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PRESIDENTIAL ADDRESS.

By Henry T. Haynes.

My first and by no means the least pleasing duty on assuming office as President of the Institution, is to thank you one and all most sincerely for the great honour you have thus conferred upon me. I fully realise the importance of the position, and, having been a member of the Council since the formation of the Institution, am aware not only of the calls upon one's time, but of the loyal assistance which that Executive has at all times rendered to my predecessors in office. I thoroughly appreciate (as one kindly member expressed it) being raised to the "Peerage" amongst engineers in this State, and although I accept with much diffidence the responsibilities of the office, I do so with every confidence that I shall receive ungrudging assistance from each one of you, and I trust that even though I may fail to adorn the office, I shall in no degree bring discredit upon it.

Having then accepted office, the obligation rests upon me to deliver an address of some sort, and thus follow as best I may, the high standard set by those who have preceded me. As an Institution, we have had life for four years, and although to some the results may be deficient of the anticipation, yet on the whole I consider the life has been worth living. Let it be known that this Institution, like many others of its kind, is worth just what value its members make it. Nothing can be more true in this connection than the words of our first President, Mr. James Thompson, M.I.C.E., "The inspiration must come from the members themselves. The Society must carry on the work."

It is gratifying to note an increase in the membership is steadily taking place, the total now on the roll being 144, as compared with 120 at the inauguration of the Institution.

One matter in which some improvement is possible, is in the average monthly attendance. Some of our most prominent members no doubt have so many calls on their time that they find it difficult to attend every meeting, but inasmuch as their wide experience would add so much to the value of the discussion, particularly to the younger members, their absence is felt to be a distinct loss to the Institution.

One other remark I venture to make with regard to our discussions, is their relative restrictiveness, if I may use the term. Comparatively few of the members engage in them, whether because the subjects are so exhaustively treated by their authors or whether due to the bashfulness so natural to many Australian engineers, is not apparent. All the same, the hope is expressed that as time goes on this will change. There can be no doubt but that personal research on any topic which may be the subject of a paper read before the Institution, is the best way to gain knowledge; and to express even a single thought, or to submit a question with a view to elicit further information from the author of a paper is the best way to stimulate interest and impress the memory. There is no piece of work in which an engineer takes so much interest, as the work he himself has had a hand in.

I proceed now to make some remarks with regard to that great branch of engineering to which I have the honour to belong, and with which I have, for over a quarter of a century, been actively associated in Australia, viz., Municipal or Local Government Engineering.

To attempt to trace the history of this worthy branch of the profession from its early infancy to the present, would be a long journey. It will suffice to say that about the first mention of the Highway Surveyor appears in a statute passed in the reign of Philip and Mary in the year 1555, entitled a "Statute for Mending of Highways," in which Act it is prescribed that "the Surveyor of Highways shall be an honest person" chosen by his fellow parishioners to serve gratuitously for a year. Modern parishioners have fallen since then, for they no longer allow the Highway Surveyor to serve quite gratuitously. But to revert to those old times, the duty was cast upon the Highway Surveyor not only to keep open and free the highways, but of "improving them," and it was under this statute that the principle of compulsory taxation to meet expenses was substituted for the earlier method of requiring the individual to provide either labour or material. A statute passed in 1691 required "The surveyor shall make every cartway leading to any market town, 8ft. wide at least, and as near as may be even and level," and "that no horse causey shall

be less in breadth than 3 feet." In 1835 the Highway Act was passed. This finally did away with the hitherto prevailing obligation of service in kind. The early years of the 17th century saw a large increase in coach traffic and the problem which presented itself to the Highway Surveyor of that day is not unlike that which presents itself to the same class of official to-day. How are we to adapt the highways to the new form of vehicle? Then too, the parish complained that it was compelled to maintain the road which was used by through traffic and which did not contribute anything to the cost. In this we have an analagous case in what we term main roads, which, I may say in passing, the State Government of Victoria has provided for by the appointment of a Roads Board, having a capital of two millions sterling. However, in England, to meet the necessities of the case, the "toll" bar was established under Turnpike Trusts. This scheme became popular and history records the fact that during the second half of the 18th century, there were some 1,100 Trusts controlling 23,000 miles of road, which cost to construct over 7 millions sterling, and produced an annual revenue of about 1½ millions sterling. This scheme did not in any way relieve the parish of its responsibility, but was intended to assist it. An attempt was made to adapt the nature of the traffic to the capacity of the road, rather than to make the road such as would stand the traffic; hence the weights and width of tyres became the subject of regulation. A great advance in Highway Legislation was made by passing the Highway Act of 1835, which provided for the grouping of parishes into highway districts, and the election of boards. This was followed by the Road Board, and now in England there are as Highway authorities—the Urban Authority, the County Council, and the Rural District Council. Every Urban authority is to exercise the office of and be the "Surveyor of Highways." The County Councils are charged with the duty of repairing main roads, and the Local Government Act, 1894, transfers to the Rural District Councils, the power of highway authorities in their respective districts.

Australia is under three principal forms of Government—the Federal, the State, and the Municipal, each with its obligations and duties clearly defined, and its natural privileges safe-guarded. There is of course, and always will be, a tendency for the greater to encroach on what are thought to be the rights of the lesser, simply because the lesser receive the authority to exercise their rights from the greater, and on the principle that he who gives may take away, when the exercise by the lesser of what during centuries of use have grown to be considered "rights," interfere with the desires and purposes of the greater, then steps are taken to deprive him of them.

Municipal Government, as we have seen, had its rise in England a great many years ago, when it began to be recognised that the people dwelling in a community had certain needs peculiar

to their locality, and which could best be met by the co-operation of the people forming that community, and so, in process of time persons were elected to see that each contributed his fair share towards defraying the cost of the convenience desired by the majority. It is assumed the people of a community know better what they want than any government can, and further, that the law cast upon the elected representatives the responsibility of seeing that the provision was satisfactorily made. This obligation as we have seen, had first reference to highways; even as early as 1696, the law placed upon the parish as a whole and on every inhabitant thereof, the obligation of maintaining all public highways, and so there grew up the principle that the local authority and no other authority had vested in it and is responsible for the care and management of the public highway. Other bodies and corporations have the right under certain restrictions to disturb and break up the surface of any street or road for the purpose of carrying on their peculiar undertaking. The principle in the law, however, recognises the right of the local authority to control the highways, and was passed in the day when only private companies or individuals conducted such business as gas, water, electric and tramway undertakings, and hence it was not only very necessary in the interests of the public that the rights of the local authority, their representatives, should be preserved, but that the means of enforcing a recognition of those rights were simple and efficient. As the provision of these conveniences pass out of the hands of private individuals and companies into the direct control of superior governments, the local authorities find it more difficult to retain the control of the highways committed to their charge, while they are in no way relieved of the primary responsibility attaching thereto. Under some of the existing conditions, roads are opened, undressed poles which disfigure our streets are erected, without any recognition whatever of statutory obligations; and hence, that condition which it has always been the effort of legislators to avoid, namely, dual control, automatically creeps in, leading to friction and dissatisfaction. It is now beginning to be recognised that the highway forms part of the machine, and that just as the railway engineer must accommodate his road bed and rail to his locomotive, so the highway engineer must adapt the highway to the character of the vehicle which traffics it. For a great many years, up to possibly the last 20 years, the general run of road-making methods remained stationary, when with the advent of motorism, the demand came for a revision of methods. In the old coaching days many of our roads were in fine condition; then with the progress of railways and the consequent decline of the coach, the roads became neglected. Now, however, a new condition has arisen, and the highway engineer of to-day must be able to meet it. All must acknowledge that good roads are essential to the development of the country as railways, and we may be quite certain that the time is not far distant when in this State

we shall find motor wagons or traction trains proposing to assist the farmer by offering to haul his produce to the railway stations at a far less rate than can now be done by horse traction, provided the road is suitable to carry the loads.

In thickly populated centres the road which is now most popular is the bituminous bound macadam. The first piece of this class of road laid by the author, was during October, 1899, when the application was little known in Australia. The method was to recoat the old road with clean basalt broken to 1½in. gauge, and top coat it with chips of the same material and well roll it with 10 ton steam roller until the surface was as perfect in form and stability as obtainable, then to sweep off any surplus dust, and to lay a 2in. coat of 1in. basalt, previously well coated with distilled coal tar. The tarred stone had been stored about three weeks after tarring, and when spread was quite tough. It was lightly rolled, and then presented a perfectly smooth and water-tight coat, standing the traffic remarkably well. At the end of 20 months it received a top dressing of boiled tar and stone chips. The only trouble was that horses not accustomed to it found it slippery. From that small beginning its application spread very rapidly. In Perth the first application of the same system was, so far as I am aware, made by the author in St. George's Terrace in April, 1906, just nine years ago, the actual cost being 2.36/- per square yard for an area of 2,353 square yards, and the work still remains, the annual maintenance probably not exceeding 1½d. per square yard. Tar at that time was 7d. per gallon and labour 1s. per hour.

Another method of the application of tar to road surfaces is in the form of a spray on ordinary water-bound gravel or macadam roads, where the tar after application is covered with sand or stone chips, and although this is very useful as a dust preventative, it must never be confounded with tar macadam or be regarded as a permanent work. At best it will not serve for longer than 12 to 18 months per application, and to be efficient should be applied every 12 months.

An important question which presents itself to every conscientous engineer is whether the character of the work he is asked to put in will last the currency of the loan (if it be loan work), or at least will not wear out at a greater rate than the sinking fund accumulates. A good many roads now being made out of 20 to 27 years currency loans will not last half of that period. Of course we can never have a piece of work just cease to exist at the date of loan repayment, but the more life it has left in it on that date, the more credit is reflected on the engineer. The ratio which the annual maintenance cost bears to the first cost is a very important question, and in the author's opinion it should never be greater than one twentieth, and ought to be less in proportion as the cost of the work increases. How-

ever, the cost limit is the factor which governs road construction as well as most other things, but in the matter of road construction it is difficult for any but the experienced expert to accurately estimate just what the cost limit should be. It is governed not only by the cost of labour and material, but by the nature and extent of the traffic it has to carry; hence, while £20 per chain might be excessive in one street, £40 per chain might be reasonable for a street of the same width in another; so that while there cannot be laid down any hard and fast rule, there should be a uniform ratio between the cost and the estimated volume of traffic.

It is not my intention on this occasion to enter on any detailed description of the various methods now adopted to meet the needs of highway traffic, but to say something with regard to the importance of municipal life generally.

First, I should like to invite your attention to the magnitude and consequent importance otf Local Government in this part of the Empire.

Local Governing Institutions were founded in Australia in the year 1839, when the first Municipal law was enacted in South Australia, which thus became the birth-place of Local Government. The first election to Municipal Councillorship took place in Adelaide on 31st October, 1840. Two years later the New South Wales Parliament passed the Sydney Corporations Act, imposing upon the Council the duty of constructing and maintaining roads, streets, sewers and water works, to light the streets and generally to look after the physical comforts of the public. In the same year, 1842, Melbourne was incorporated under a Special Act as a town, and raised to the dignity of a city in 1847. Geelong, in Victoria, was incorporated under the same Act in 1849. These two Municipalities still control their local affairs under these old Acts as amended, and they are the only two in Victoria which do so, and are allowed to elect Aldermen. In 1842 an Imperial Act empowered the Government of New South Wales to incorporate any part of the country for the purpose of Local Government under District Councils. Under the Imperial Act of 1850, which granted to Victoria responsible government, power was given to divide the State into Local Governing Districts.

In Queensland, Local Government was established by the incorporation of Brisbane as a Municipality on 7th September, 1859, by proclamation about three months prior to the separation of that State from New South Wales; and by an Act passed by the Queensland Parliament in 1861, power was given for the incorporation of any city, town or district on petition to the Governor signed by 100 resident householders.

Our own State was the last of the group to be granted the privileges of Local Government, the first Act being passed in January, 1871.

The Local Government Statutes in all of the States have undergone considerable change and enlargement as settlement has taken place and local needs have become more pressing. The central idea is that the local governing body shall be the local highway authority. Its primary duty is to construct and care for the roads and bridges within the area under its control, and although at times by reason of the increased traffic due to rapid settlement and increase of commerce, local authorities have been hard pressed to find the means to meet the demands for better roads, and although they have had to appeal to the Central Governments for financial assistance, which where possible and warranted, has always been readily given, they have very strongly opposed as an interference with their natural rights as Local Governing Bodies any attempts by the Central Governments to enter their districts and make the roads without their consent, although as time rolls on there seem to be indications that these rights will become more a relic of the past than a possession of the future.

At the present time the various local governing statutes vary considerably in detail, still in principle they have the same object in view—the provision of all those conditions which tend to conserve and promote the physical well-being of the people, in the matter of highways, public health, sanitation, pure water, wholesome food, correct weights and measures, recreation, libraries, transport, the support of charitable institutions and the prevention of loss by flood and fire.

Victoria was, I believe, the first State to introduce a very comprehensive system of Local Government, due possibly to the rapid development which followed the gold rush in 1852.

The Roads Act passed in 1853, makes a distinction between main roads and parish roads; the main roads being placed under the care of a Central Road Board, while parish roads were made and maintained by District Councils.

It is very interesting to note that after a lapse of 60 years this system should be reverted to by the establishment of the Country Roads Commissioners, which was appointed on the 26th March, 1913, under special Act entitled the Country Roads Act, with a capital of £2,000,000 to be expended in five years.

The Central Road Board before referred to was abolished by the Shires Act passed in 1863, which was the real beginning of a system of Local Government, and which did yeoman service for the early settlers of Victoria. Victoria was the first State to recognise the importance of placing its Local Government expenditure on works in the hands of none but the skilled engineer. In the L.G.A. of 1874, 41 years ago, a clause was inserted requiring persons before appointment to the position of Local Government Engineer to hold a certificate of competency, nor would the Government pay to any Council any special money grant until a

certificate that the work in respect to which the grant was voted was certified to by a certificated engineer. The result was that the Municipal Engineer in Victoria became an entity, and the certificate though difficult to obtain, was eagerly sought after.

Another important provision in the 1874 Act, was an annual endowment of £310,000 for Local Government, which, in later years, was increased by Parliament to £450,000. With a gift of so large a sum annually, it was but the exercise of ordinary caution on the part of the Government to see that the actual expenditure was under the supervision of the qualified engineer.

In New South Wales the development was much slower. The original Act of 1858 served for nine years, when the Act of 1867 was passed. This served with certain amendments, and amid much complaint until 1905, some 38 years, when the Shires Act became law. This was further developed in 1906 by the passage by Parliament of The Local Government Act, 1906, under which Act, with subsequent amendments, the Local Government of New South Wales is administered. It may, however, be mentioned that of the State's area of 310,367 square miles, only 183,569 square miles are incorporated, the whole of the Western Division being excluded. To give an idea of the magnitude of some of the areas over which the Local Government Engineer has charge, one shire has an area of 5,730 square miles. It further serves to emphasise how important it is, from an economic standpoint, that the person charged with the spending of public moneys over such a wide area should be thoroughly trained and well qualified for his work. It is certainly not the place for the untrained amateur, however well-meaning he may be, and this the legislature of New South Wales recognised, because it included in the Act a clause prohibiting the appointment to the position of engineer, any person not holding a certificate of qualification.

In Queensland, Local Government passed through all the evolutionary stages, each an improvement on its predecessors, the first Act being passed in 1861 and amended in 1864, until 17 years later the Local Government Act of 1878 became law; but this Act, although based on the Victorian Local Government Act, did not apply very satisfactorily to the vast areas of Queensland; hence in the next year a new Act was passed, creating Divisional Boards and was applied to 660,000 square miles of country exclusive of existing Municipalities. This huge area was divided into 72 divisons. Subsequently, and as a result of a Royal Commission, a new Act was passed entitled the Local Authorities Act 1902, which, with amendments, is the law under which Local Government is now administered in Queensland. The Queensland Act of 1902 does not require the engineer to hold any qualification, but it provides that the Minister may order an Inspector to examine any local work or to supervise its execution and prohibit the local authority making any payment on account thereof, unless on the certificate of the

Inspector, and further the Inspector may be called upon by the Minister to report on the competency of the officers of the local authority to undertake and satisfactorily complete any work in respect to which the State Treasurer proposes to advance money. All this may be very necessary under the circumstances, but it is very humiliating to any one filling the office of engineer.

Local Government in W.A. is of two kinds, operating under separate Acts, known shortly as the Municipal Corporations Act 1906, and the Road Act 1911, the official titles of the governing bodies being in the first, Municipal Councils, and in the second, Road Boards. The Acts have much in common, though differing in some matters of importance which it is not now convenient to review.

Of Municipalities there are 38, 14 of which are in the Metropolitan Area, and 24 in the more closely settled portions of the country and Goldfields. There are 110 Road Boards, which administer Local Government over an area of 975,809 square miles, while the area administered by Councils is only 111 square miles, making a total of 975,920 square miles, the area of the whole State. The first Act relating to Municipal Government became law on 2nd January, 1871, under which Perth, Fremantle, Albany and some half-dozen other principal centres were gazetted Municipalities in the early part of 1871. At present Municipalities are working under an Act passed in 1906, and the Road Boards under an Act of 1911, and although Bills dealing in a more comprehensive manner have been drafted, they have not yet received the sanction of Parliament. There is no clause in either of the existing Acts requiring engineering qualification, but it has been promised that when the Local Government legislation is again under review, the subject of engineering qualification will receive consideration.

I am led at this stage to make some reference to the status of the engineer in this State, particularly in its Local Government branch, although my remarks are not entirely without general application. It has appeared to me a matter for regret that the profession has no legal status. Any person having a limited practice and knowledge may receive an appointment if he has a sufficient number of friends to obtain it for him, which, in my opinion, is not in the interests of the profession nor of the public. The tendency of such a condition seems to me to cause young men to disregard the importance of plodding patiently along the dreary way of investigation of principles and theories, and to give more attention to the less tedious and more remunerative application of the results of others, and when in difficulty to enquire of a neighbour. The establishment of our University should, and no doubt will, tend to cure this, but the cure would be much more certain if all save those who attained a standard were discouraged. There are gentlemen in this State holding engineering positions of com-

parative importance and under whose direction and management considerable sums of money are annually expended, who in some of the Eastern States are barred by Statute from similar positions in the smallest Country Shire or local authority, and we may find the appellation "Engineer" following the names of men who are ignorant of the first rudiments of the profession in any of its branches.

I do trust it will not be thought I am desiring to create a close corporation for engineers or that I am seeking to place obstacles in the way of any man's progress, nor am I supposing that the mere non-possession of a statutory certificate necessarily indicates that such a person is unqualified to perform engineering work. My desire is to elevate the profession particularly in its Municipal branch, so that those who attain to it may realise that they have achieved something that was worth while, and further that the public may have greater confidence that the men they employ are thoroughly qualified, while the men themselves may feel they are eligible for appointment in every part of the Commonwealth. I am not unmindful that hitherto the young engineer and engineers generally, have laboured under great disability, some isolated in distant parts of the country, and when in town restricted to a somewhat narrow routine, working for the most part to standards and in strict accordance with regulations without much opportunity for the exercise of initiative. He becomes a sort of specialist it is true, but pretty much like the factory girl who specialised in sewing buttons on with a machine, and when the machine broke down could do nothing because she had not learned how to sew them on by hand.

As I have before suggested, our University conducted as it is with such remarkable liberality, provides a means whereby any person having the necessary preliminary education may be thoroughly trained in all the principles of the profession. I venture to think the time has arrived when steps should be taken with a view, not only to raise the status, but to ensure a high degree of efficiency and economy in design and execution; to obtain a statutory bar to any person, under a certain length of experience in any particular branch, styling himself or practising as an engineer. We are all aware that there exists such a bar with respect to unqualified lawyers, doctors, dentists, surveyors, and even the humble, though important, position of Health Inspector. And important as all these professions undoubtedly are, they are not more so than the profession of engineering, dealing as it does, not only with enormous sums of money, but with the safety, comfort, and continuance of human life, in our railways, water supply, sewerage, harbours, highway construction, and many other undertakings so necessary to civilised humanity. It was the late Sir James Clarke Inglis, M.Inst.C.E., General Manager and Engineer of the Great Western Railway, who said, "It does not require great

ability to handle a situation in which resources are boundless. True ability is that which can get the greatest results out of the least means and without the detailed knowledge of principles this is impossible."

It may not be without interest to refer shortly to the standards set up by the New South Wales and Victorian Local Government Acts and also by the Institution of Municipal and County Engineers, England. In New South Wales candidates for certificates of qualification as Local Government Engineer are required to pass an examination in the following subjects: Laying out and construction of roads, bridges, etc.; theory and design of structures and strength of materials, drawing, preparation of specifications, calculation of quantities and estimates of cost, surveying, hydraulic and sanitary engineering, and the examining board consists of four engineers appointed by the State Government, one of whom is a Local Government Engineer of standing.

In Victoria, the examination embraces: Surveying; principles of engineering construction, as strength of materials; beams, columns, arches, factors of safety; production and transmission of stresses, and strains in structures; special structure in stone, brickwork, concrete, cast and wrought iron or steel; reinforced concrete; drainage and sanitary engineering—discharge from water sheds; flow of water in channels, pipes, etc.; treatment and disposal of sewage; road and street engineering; location and grading; town streets; construction and maintenance; cleansing of roads and streets; design of bridges and culverts in masonry, timber, iron or steel, and retaining walls; and the examining board consists of three engineers—the Professor of Engineering, Melbourne University, a Local Government Engineer of standing and an engineer belonging to the State Department of Works.

The Institution of Municipal and County Engineers, England, conducts examinations, and, while the certificates issued have no legal significance corresponding with those issued in New South Wales and Victoria, they are recognised by Local Governing Bodies as being a satisfactory indication of qualification. The subjects are: Sewage disposal; tramway construction; bridge construction; water supply; geodesy; hydraulics; sewerage; road construction and maintenance; materials; construction of public buildings; building bye-laws; public baths and hospitals; Municipal and Local Government law.

It will be gathered from this that the standard in England is much higher and comprises a knowledge of a wider range of subjects than in New South Wales or Victoria, and in Victoria the standard is somewhat higher than in New South Wales. The purpose in referring to these examinations is to indicate the standard of efficiency required by local governing bodies in the Eastern States and in England.

Passing now to something of a more concrete character, with a view to showing the magnitude of engineering works carried out by local governing bodies in Australia, I desire to point out that during 1912, Local Government authorities in Australia expended in public works, four million pounds out of revenue alone, and a very considerable sum from loans, there being raised during the year £2,076,486. In any case the amount expended in works could not have been far short of five millions sterling amongst the 1031 local authorities.

Western Australia	148
South Australia	178
Victoria	208
New South Wales	324
Queensland	173

The net revenue of all Local Governing Bodies during 1912 was $7\frac{1}{4}$ million pounds, which, with loans raised, increased the amount to 9 1-3rd millions. I merely mention this to indicate the large responsibility which is cast upon Municipalities. It is not my desire to burden you with a host of figures, nor indeed to use one single figure more than will serve my purpose of showing you the importance of Municipal engineering, a branch of the profession which I fear in this State at least has not hitherto received its due consideration. Private enterprise has done much; State Governments have done their best; Local Governments have made mistakes and in some measure failed of their highest possibilities, still it is doubtful if any institution or combination ministers so much and so well to the physical needs and comforts of the people. Certain it is that no spender of public moneys can get so much value for money expended as Local Governing Bodies; but these even might do better if their public works administration and expenditure was entirely in the hands of the highly-trained and capable Municipal engineer instead of, as we frequently find it, in the hands of the well-meaning though untrained official.

Australia has an area of approximately 2,948,366 square miles, of which 1,963,122 square miles are incorporated. Practically one million square miles are unincorporated:

New South Wales	126,798
Northern Territory	523,620
South Australia	334,219
Federal City	910

There are 1,031 Local Governing Areas under the title of Municipalities, District Councils, Shires, Road Boards, having a total annual revenue of approximately $7\frac{1}{4}$ million pounds; an expenditure on engineering works of £4,100,000 exclusive of loan expenditure, and these figures represent a considerable direct taxation and should in themselves be sufficient to indicate the great and important service which is cast upon Local Governing Bodies and inci-

dentally the obligation which rests upon the officers who are charged with the responsibility of seeing that the money is efficiently and economically expended. Throughout the whole area under Local Government control there are upwards of 200,000 miles of roads, of which 70,000 miles have been more or less improved, while 130,000 miles are merely formed or in a state of nature. The mileage of roads is ever increasing as settlement proceeds and great tracts of country are subdivided. The figures given can only be taken as approximate, although compiled from such official records as are available. The purpose is not to give an absolutely accurate record so much as to indicate the magnitude of the work which lies before the Highway Engineer, and incidentally to suggest the enormous annual loss which the people who are compelled to carry goods and travel over the 130,000 miles of unformed roads must sustain. In the country districts of this State it is usual to estimate haulage at 1/- per ton per mile, and in some cases I know it is larger, and further that over some of the roads it is not possible with a two-horse cart team to haul more than one ton weight. According to Local Government returns there are at least 21,691 miles of unmade roads in Local Government areas in this State, which, at the low rate of £900 per mile, would require an expenditure of something like 19½ million pounds sterling to construct; and yet as engineers I feel sure that we have every confidence that the work is by no means beyond the State's merit or resources, and further, I will venture with all seriousness to say that the economic value of good roads is such that wherever there is sufficient traffic to warrant a road at all, it pays to make it a good one, and the reduction in cost of haulage per unit of weight and distance is such that all capital cost charges could be paid, and a margin left.

The expenditure actually incurred in connection with the construction and maintenance of roads during the year 1912-13 amounted to £3,400,000, exclusive of loan expenditure, and it is interesting to note that in Victoria and in South Australia the amount expended on maintenance was about double that expended on construction, while in New South Wales the amounts are about equal. In Western Australia under Road Boards, the expenditure on construction is about double that on maintenance—a condition of affairs one would expect in a State which is so rapidly developing. With regard to the Shires of Victoria, I find the expenditure on maintenance and construction about equal, the actual figures being £263,952 and £265,669 respectively. I think a consideration of these particulars should serve to emphasise the wisdom of skilful and substantial road construction, with a view to the reduction of maintenance to the lowest possible figure, particularly in this State which has so many thousand of miles of roads to build, and it is almost a pity that detailed information is not available which would enable one to ascertain the ratio which the cost of main-

tenance bears to the first cost and mileage of the various classes of roads constructed. Such information would be invaluable to the Local Government engineer and would probably be an unanswerable argument and would serve to check the tendency which is too prevalent to sacrifice stability to undue low first cost. As individual members of a great utilitarian profession we need to bring too bear all the energy of our wills to oppose this baneful tendency and to remember the greatest economy is to be achieved by skilful design, careful execution and proper organisation, rather than by the production of low grade work.

In addition to designing and caring for the highways, demand is made on the Municipal engineer for the exercise of expert knowledge in many other departments. He must be able to satisfactorily deal with problems in storm water drainage, bridges, tramways, sewerage and sewage disposal, sanitation, water supply, gas and electric undertakings, buildings. In fact the work which engages the attention of the Municipal engineer is of necessity very varied. He is required to keep in close touch with all modern improvements which are from time to time introduced in various parts of the world to meet the demand of an ever exacting public. The inventive genius of the few creates the need of the many and the engineer is called upon to meet that need. As a community becomes more educated and its life more strenuous, so it seeks greater convenience, comfort, healthy and pleasing surroundings, a higher standard of sanitation, a more picturesque lay-out and finish of thoroughfares, means of rapid and smooth transit, thus considerably increasing the responsibility of the Municipal engineer and compelling him to realise that he must grow or die; to stand still and live is impossible, and to attempt to do so is to throw himself into the backwash where after drifting aimlessly for a little he finds himself cast on the bank never again to enter the stream of life and work.

It is only of recent years that the Municipal engineer has been called upon to study the aesthetic features of the lay-out of towns. Formerly the land surveyor, slavishly bound by his right angles, laid out the lines of road without any regard either to contour, level, or aesthetic appearance—straight over the impassable barrier of rising ground, down the precipitous slope into the valley, crossing the stream at any angle to its course which seemed most convenient, leaving it to the engineer to deviate to more suitable and correct lines of communication. This in country districts is comparatively easy where land is sparsely built upon and where drainage ways may be acquired at low cost, but in cities and towns, where, as is the case in many instances within the author's own knowledge, the lowest level of the surface of the road is not at an intersection, but mid-way between cross roads at both ends. Such a street closely built upon presents not only difficulties in drainage, but very costly work to render the locality comfortable for

occupation. The energies of the Municipal engineer are being directed to deal with these objectionable features and his advice is now sometimes sought to obviate their recurrence, and also in the development of lands for building areas. I am beginning almost to think he will require to add the profession of landscape gardener to his many qualifications; certain it is that he must be able to foresee the purpose and effect of street cultivation, of ornamental plots and of garden reserves in the public highway.

One of the greatest problems which confronts the Municipal engineer is how to reduce the number of street openings in connection with sub-surface services, such as water, gas, sewage, telephones. In the latter service the postal authorities have wisely selected the footpath, and it is very gratifying to note that only quite recently the water authority has adopted a similar course. This, however, does not get over the difficulty of transverse openings for domestic services, although it in a measure minimises their number, and this is a matter of very great importance, more particularly since the advent of wood-paved and bituminous-bound macadam, because the perfect reinstatement of openings of such roads is a work of the greatest difficulty and requires the greatest skill, and as Lowell says: "The world advances and in time outgrows the laws that in our father's day were best." I am beginning to think the time has arrived when local authorities should be given the power when the laying of a permanent and costly road-pavement has been determined upon, and prior to carrying out the work, to require the owner of all gas, water, and such like perishable conduits and services, to open the road and examine and substitute good pipes for any that may appear defective, and to lay any new services that might be required, on the understanding that no subsequent permission to disturb the permanent pavement would be granted for a term of years, save only where absolutely necessary in case of a leak, and even then under substantial compensation. An alternative suggestion which might give our gas and water engineers cause for reflection is to lay future water and gas reticulation pipes on lines similar to those adopted by the Sewerage Department, that is, via back right-of-way or adjoining the back fence of back to back allotments, thus keeping the pipes out of the streets altogether, save only at crossings. Fire services could be provided for by branches to the frontages at suitable intervals. Yet another alternative which offers is to lay sub-mains under each side-walk, and, although this might incur a somewhat larger outlay for mains by the gas or water authority, the reduction in the length of service lines would be such that, as a whole, the total outlay would not be much in excess. In any case the difficulty arising from pavement disturbance would be solved, and that is my chief object just now. Where road openings are made the Municipal engineer finds it almost impossible to obtain a satisfactory reinstatement, due possibly to the fact that the persons effecting the repair do not appreciate its importance.

It is extremely important that the foundation of the opening shall be so consolidated that further settlement is practically impossible. This can only be done by much patient labour in damping the filling material and consolidating it in thin layers, so that when the pavement is relaid its surface shall coincide exactly with that of the road adjoining and remain so with no risk of settlement. The common practice of refilling so as to allow for settlement is bad, and very unsatisfactory, for the reason that the amount of settlement can never be accurately gauged, and consequently the result is either a hump or a depression all the time. Any irregularity in the surface accelerates destruction by wheeled traffic, because there are introduced quite a different set of conditions than arise from the traffic on a perfectly smooth and unyielding surface. In the latter case there is little other than the influence of direct compression due to the weight carried, while in the former there is the added influence of impact increasing with the square of the velocity and with the depth of the depression, and also the lateral thrust in the direction of the advancing wheel causing or tending to cause the road crust to travel laterally or be pounded and acting at its maximum probably in a plane about one-third the depth of the depression. Inasmuch as the modern road crust in an asphaltic or a bituminous-bound macadam road will not exceed 4 inches in thickness, it is manifest that the resistance to depression must be borne entirely by the foundation, hence the importance of selecting high-class resistant material and regulating the thickness of that material so that the heaviest load likely to be applied will be distributed over a sufficiently large area of the earth below that there shall be no subsidence, because, after all, it is the natural earth which is to carry the load and the artificial foundation has practically no resistance to cross breaking or deflection unless it be of cement concrete or be reinforced, and the man who opens a road pavement should not feel satisfied that he has done all that can reasonably be expected of him when he has put back all that he took out.

An important phase of the question which demands investigation is the suitability of the stone and other material used in road work. In England and elsewhere, particularly France, whose road makers are said to be the best in the world, investigation of a highly scientific as well as practical character has been going on for very many years, with the result that the various rock has been tested not only in the laboratory and under the miscroscope, but on the highway under different climatic conditions and density of traffic. The results have been tabulated so that now the road engineer may know with a considerable degree of certainty the behaviour of any piece of road which he constructs and need not incur the expense of laying experimental pieces of work. In the United States of America also, the officers of the Federal Geological Survey have compiled a lot of very valuable information on the subject of road-making rock.

It would, I consider, be a very excellent and economic undertaking if engineers engaged in road-making and the officers of our Geological Department and the engineering branch of the University, could co-operate with a view to similar investigation. Under existing conditions the stone used in road construction may be of any class provided it answers to the generic term of granite or diorite, and in a truck of five tons weight one may receive half-a-dozen grades of either material. There has been no attempt, so far as I am aware, either on the part of our quarry managers or general users to ascertain the relative merits or suitability of any stone that is used. Many important considerations are involved in the selection of stone, such, for example, as hardness, toughness and binding properties, also its absorbtivity, its physical structure, and whether it was undergoing or had recently undergone change which was likely to produce early disintegration. Large ratios of felspar are said to contribute dust in summer and mud in winter, while hornblende tends to toughness, and therefore was a valuable property.

The microscope is a valuable instrument in investigating the suitability of the stone as regards its structure, but the preparation of the specimens requires considerable skill and care and the use of very true machinery. The specimen is first sawn to about 1-8 of an inch in thickness and then one face ground perfectly smooth and afterwards cemented to glass. The other side is then ground truly parallel and so thin that the specimen becomes transparent. A microscopic examination of this thin specimen reveals the size of the crystals. Rocks having small crystals are better than those in which the crystals are large, and again those in which the crystals are well interlocked are tougher than those otherwise. The presence of small cells, while a disadvantage from the point of view of crushing resistance, are valuable where bituminous compounds are to be used as binders. Stone containing minerals which reveal distinct lines of cleavage are not desirable for road work, because of their tendency to disintegrate under traffic. The investigation is one of very considerable importance and would form a very interesting subject for a research by some of our younger members.

As this Institution represents engineers in all branches, I am tempted to refer to a matter which has occupied my mind for some considerable time—the narrowness of the opening to members of the profession who desire to enter upon private practice. I am aware than for a long time it has been the practice of local authorities who are without professional officers to apply to and obtain the services of engineers who are on the Public Service staff, with the result that some of our brethren in private practice suffer hardship. It may be offered as a justification that the money to be expended is public money, and that the local authorities are generally short of funds. This is hardly a sufficient justification

for rendering gratuitous service and any local authority having public money to expend would save by placing that expenditure under skilled supervision, rather than by obtaining engineering advice and the supervision by a foreman. I think the private practice engineer should receive some encouragement, otherwise the State may lose the benefit of the initiative in design and economy in execution that the engineer in competition with his brethren would supply. It seems to me that after the calamitous war now raging there is a great future for the engineer in Australia. Australia must be developed. The civil and mechanical engineer is indispensable, and although the last century witnessed great advances not only in the theories of the scientist and the application of those theories by the engineer, much greater advance will take place in their application to the needs of this land in the near future, and with every respect to the engineering staff in the Public Service of the Commonwealth, I sometimes think that much good would result if occasionally, at least, the design and execution of certain public works of importance were thrown open to the engineering profession of Australia.

Our younger members should remember that their sphere is ever becoming wider, and with the increasing settlement, development and wealth of the State will continue to expand. If they are well equipped when the call comes, they will find ample room for their abilities.

THE PLACE OF GEOLOGY IN THE TRAINING OF AN ENGINEER.

By Prof. Woolnough.

I must disclaim any intention to-night of coming here to instruct such a body as this. I come here to receive instruction, and I trust that you will bear this in mind and criticise my statements this evening as freely as you can, in order that I may learn how to treat my engineering students in future in the matter of geology.

The bulk of the students with whom I have to deal in the first year belong to this profession, and I am extremely anxious to make the subject of geology useful to them, if it can be made useful; and if geology cannot be made useful to engineering students, I should like to hear the reasons why it is held to be of no value, and then I shall be equally glad to see it cut out and more useful subjects put in its place. I think, however, I may be able to show, from my side at all events, that I consider a training in geology to be of very considerable value to the student engineer. The breadth of the scope of geology, and the number of specialisations in engineering, make two very broad subjects, and it is natural that they should over-lap at several points.

There can be no question at all, I think, of the immense importance of the knowledge of the scientific aspects of geology to a mining engineer, and I do not intend in any way to stress the necessity which there is for a mining engineer to have an ample training in geology.

It may be rather difficult to see that the specialised life of an electrical engineer comes into contact in any way with the subject of geology, but, in so far as the electrical engineer requires a broad basis of civil engineering training upon which to found his more specialised work, I think the electrical engineer comes into the same category as the civil engineer; and it is, therefore, more with the civil engineer that I intend to deal to-night, rather than with specialised branches of the profession.

We may divide the advantages of geology into two classes: (1) The specific application to every-day practice. (2) The general cultural effect of the study of the subject.

Under the specific applications to engineering, it is only necessary to mention a few to convince you, I think, that geology has a very direct and practical bearing upon many of the branches of civil engineering. Under material geology we may mention the subjects of coal, building stones, road metal, sand and cement materials, clay and bricks, petroleum and natural gas, metals and water. Under structural geology we may mention the effects of

geological structure upon foundations for buildings, railways, docks, etc. Under dynamical geology comes the work of the atmosphere, of rain and rivers, in erosion of the land surface, and the problems of sand drift, both marine and sub-aerial.

Under the physiographic side of geology we have to deal with the scientific origin of topographic features, the distribution and origin of mountains and valleys, the latter particularly in connection with the location of railways and roads, and in connection with irrigation and water supply, harbours and coast lights, all of which features are very important for the civil engineer. The circulation of the atmosphere and the circulation of land waters, the effects of topography on rainfall, running-off of the water, erosion, silting up of dams, weirs, the salt problem in water supply and very many others of this character are equally vital. Doubtless the list may be swollen very considerably from your own experience of the points of contact between the natural phenomena of the earth's surface and your own particular profession.

The results of lack of geological knowledge on the part of engineers have been responsible in the past for very many costly failures and in not a few instances for serious loss of life and property. I may perhaps mention one or two examples of instances of lack of knowledge of geological structure on the part of engineers leading to quite serious results. Many of you are familiar with the railway line up Mount Lofty from Adelaide. The railway line from Blackwood runs on the right hand side of a rather steep spur. It would, I think, have been equally easy to have carried that line on the other side of the spur. The Mt. Lofty ranges are built up of a series of very ancient sedimentary deposits which dip steeply towards the right-hand side of the spur. The result has been that on numerous occasions that line has slipped seriously, causing delays to traffic and necessitating costly repairs. Had the line been taken up the other side of the spur, the rocks, instead of being in a position of unstable equilibrium, ready to be shaken down by the vibration and weight of passing trains, would have been in such a position as to have locked themselves more securely than ever under the stresses. Another example from railway engineering was one I had an opportunity of seeing not very long before I came to Western Australia. It is on the new North Coast Railway in New South Wales. And there again the railway has been built on the side of a ridge towards which the rocks dip, causing a position of unstable equilibrium. In this case no accidents have occurred since the opening of the line, but during the construction of the line a very serious land-slip took place and delayed the construction for a long period of time. These are only two instances. In this latter case there are several other factors which enter into the subject, all of which might have been allowed for had the fundamental principles of geological structure been taken into consideration fully when the railway was being constructed.

If it be admitted (I am quite prepared for you at the close of what I have to say to controvert the idea that it should be admitted at all), if it be admitted that it is advisable for an engineer to know something of the numerous applications of geology in his profession, it must equally, I think, be allowed that it is essential for him to undertake a carefully-prepared and consecutive course in the subject. The direct applications of geology to engineering do not by any means confine themselves to the more elementary first principles of the science. On the contrary, many of them involve quite a considerable knowledge of its more advanced branches. To know simply the results without knowing the reasons is like attempting to run before one can walk, or like attempting to design a Forth bridge before one has learned the very elements of mechanical drawing. In order that a due appreciation of the ultimate applications may be obtained, I think it is essential that the student should proceed by logically arranged steps from the first cause to the effect, otherwise he is bound to get false perspective in the subject. I have been criticised severely for teaching crystalography to the engineering students, but crystalography is just as essential to a knowledge of material geology as is the study of descriptive geometry or applied mechanics to engineering drawing and design. The whole study of minerals rests on a basis of crystalography, and a study of rocks (petrology) rests upon mineralogy, and all the ramifications of structural and dynamic geology rest upon petrology, so that if we are to learn the details of structural and dynamic geology which come most closely within the province of the engineer, I believe it is quite essential to start from the beginning and to learn the A.B.C., which in this case consists of a knowledge of the forms of crystals in order that an adequate conception of the ultimate aim of the subject may be obtained. To become highly proficient in the wide range of geological subjects embraced in the list I have given, means that a man must be a professional geologist. Please note I make a qualification here—to become highly proficient in these various branches. A leading scientific educationalist in America, Professor H. S. Williams, estimates that a geologist needs from 4 to 5 years of continuous training after he has learned how to study, that is after his first year at the University for we regard students in the first year as being only in the position of learning how to study. This, of course, is absolutely out of the question for the engineer. He does not expect to become a professional geologist. It is obviously not essential for him to be a geologist of such skill and experience as to be able to investigate all the intricate geological problems that come in his way in the course of his practice. It is quite sufficient that he should know enough about the subject to realise when he is face to face with such problems, and when it is desirable or essential for him to call in the aid of the professional geologist. Further, he should be able from his training to follow intelligently the methods which are used by his con-

freres, and to realise fully the actual significance of the results obtained. I know of several instances where the report of specialists was obtained at considerable expense, but, owing to the lack of training on the part of the engineer, the advice given was misunderstood, and therefore the whole of the expense involved in obtaining the services of the professional geologist was really thrown away. The result was failure, and the blame fell, not on the engineer, but on the geologist, as the engineer simply got out of the trouble by saying that he had taken the advice of the geologist. As I have said before the advice was misunderstood and the results were mis-applied. I think, in justice to my own profession, it is fair that this should be recognised to some extent at all events, and that the possibility of such a result should be realised. Possibly it has never happened in Western Australia, but what I speak of has happened in other parts of the world. The Western Australian engineers would, no doubt, n blame the geologist under like circumstances.

My own personal opinion is that every engineer should take the full introductory course of geology in connection with the University work, and in that way obtain a broad general outlook on the subject, sufficient for him to build up later a more specialised knowledge in any required direction. I think, however, that civil engineers should go further, and take, perhaps, one term's work in their second year, and in that term attend a course of carefully arranged lectures, with practical work specially suited for their requirements. Mining engineers must, I think, have a very full course of work on economic geology and upon ore deposits, and I against it. Once a student has passed through a training in minera- think that that course cannot be given in less than about four terms, that is, in our University arrangement, a year and a third after the completion of their preliminary course in general geology.

In the second place we must consider the place of geology as an instrument of general mental culture. The bulk of the train ing of the engineer makes for mathematical exactness. Now I am speaking, please, about a subject of which I know nothing at all, and therefore I speak with all the conviction of ignoranc. You will, please, at the close of what I have to say, correct me in any place where I have made a serious error, but I think from what I have seen of the engineering courses that the bulk of the training of the engineer makes for mathematical exactness, with the almost inevitable concomitant of a restriction of view. In his elementary training, mathematics, physics, and chemistry necessarily form the backbone of all his studies. In their elementa- stages at all events (I do not mean to refer in this respect to advanced physics and chemistry), in the elementary stages of physics and chemistry and mathematics, the students work out carefully planned experiments in which cause follows effect with the same

certainty that night follows days. He knows before he starts an experiment what the result of the experiment is going to be, and his entire aim is to carry out the processes of the experiment with such exact care and such rigid application to detail, that the highest possible degree of accuracy shall be obtained in the results. Studious exactness in every point of detail is what becomes impressed in his mind. The great aim of physics is to isolate the forces of Nature and to study their effect separately from one another. The object of chemistry is to isolate substances and to obtain them as pure as possible, and in this pure state to study their properties. It is this idea of isolation and narrowing down which possesses the mind of the student in his early stages, and, unless it is counterbalanced in some way, it tends to narrow his personality, both as an engineer and as a citizen—a very undesirable effect from either point of view. There are very many studies which tend to neutralise this narrowing tendency—art, literature, music, history, and so on. Most students, however, have not sufficient ability or quickness of mind to permit them to stray very far into these delectable paths. It is only the man of exceptional brilliance who can afford the time or the mental energy necessary to make an excursion into these branches of knowledge, so far removed from his special study. Geology, I think, supplies the need for a broadening principle to a certain extent, and, at the same time, it is sufficiently closely in touch with the problems of the every-day life of the engineer to be fairly reckoned within the sphere of his necessary knowledge. I do not wish to infer, by placing geology as a sort of antithesis to physics and chemistry, that it lacks entirely what they possess in the matter of exactness. A good many people criticise geology and state that it is a science of inexactness, but in very many of its aspects geology is every bit as exact as the most exact branches of physics and chemistry. Certainly there are numerous unexplored paths in geology which are very hazily defined indeed, and when one gets into these the lack of exactness is very seriously felt, but it is the aim of the geological investigator always to arrive ultimately at an exactness of as high degree as is possible in the nature of the subject. There are very few of the branches of geology, however, in which a student cannot catch glimpses, at every step, of vistas of fascinating speculation leading away to the very infinitudes of time and of space. The great expanse of thought is a very good strolling ground for the student during his hours of relaxation, and the air of such a country is surely stimulating, and is a wholesome change from that of strains and stresses, differentials, integrals and logarithms. Geology, as distinct from mineralogy and petrology, has the advantage of being essentially an observational science. In mineralogy and petrology the science has reached exactness, and measurement is the object of the investigation. In this respect it does not differ essentially from either chemistry or physics, in fact, mineralogy is very

largely chemistry applied in a very highly specialised manner. Petrology is very largely a question of physical optics, and in these branches the student has all the training, that he gets either in the chemical laboratory or in the physical laboratory. In field geology, however, the observational character of the science is present to a much higher degree than in physics, chemistry and engineering. "The training of the eye to take in quickly and comprehensively all of the essential points of a complex and often obscure phenomenon, and the training of the mind to observe accurately, to record correctly, to compare, group and infer justly and to express cogently the results of these menta functions," as Williams puts it, are developed in a very high degree in the study of geology in the field. Another advantage is that many of the phenomena are simple and grand, and they are concrete in character, not abstract as are many of the finest conceptions in the other sciences, and in the concreteness of geology lies one of its very great advantages for elementary students, who, in the rest of their work, are surrounded by those abstractions.

The universality of the applications of geology cannot be questioned, and as a companion to travel its value cannot be over-estimated. A good grounding in the elements of the science not only keeps a man's eyes open and keeps his rasoning powers alert, but, wherever he is travelling, under any conditions, whether in company or alone, he has with him a constant companionship o Nature. I can speak with some experience with regard to this. in travelling quite alone in many parts of Australia; I have found that the knowledge of geology, and particularly of physiography, has been as good as a companion with me all the time, and I think any man who has studied even the elements of the subject cannot fail to feel this companionship of Nature as he is travelling about the country. The feeling of companionship makes him enjoy the beauties of Nature more, and I think he feels the discomforts less, than does the man who is oblivious to the forces at work under his eyes, and utterly forgetful of the greater and quieter forces which have been working through all the ages to produce the environment in which he finds himself. The study of physiography is even better than geology from this point of view. The lines are broad and the colours are striking, and, as the great developer of physiography, Professor W. M. Davis of Harvard, says, "He who runs may read, in this science." This fact tends towards lack of thoroughness and exactitude, a tendency very marked in a good deal of the work of physiographers, and a tendency which requires careful counteracting, and to which the study of mathematics and physics is a wholesome antidote. The various sciences, geology on the one hand and chemistry and physics on the other are, I think, complementary to one another in the training of the mind. Geology by itself would have too much tendency to broadening and too little training in exactness, while

chemistry and physics on the other hand, taken alone, have, I think, rather a tendency to limit a man's interests.

Physiography is of immense value to the topographer, explaining the reasons for the various features he is mapping; and, surely, in this way it makes both for completeness and for accuracy in his work. His map becomes a living, vital, thing, and a thing of progress and development, and not simply a dead mass of hills and valleys. There can be no doubt, in my mind, too, as to the immense value of geological map reading. It is of much more value as a mental training than ordinary topographical map reading. The preparation of geological sections from the surface maps develops the sense of the third dimension, and, as a teacher in this subject, I have been astonished to find that probably not more than about 2% of people live, naturally, in a world of three dimensions. The vast majority of people reason, to all intents and purposes, in two dimensions. Even quite brilliant students fail, for a long time, to grasp the idea of depth conveyed by the data given upon a geological map. I do not know what the origin of this tendency is; I suppose it is that we travel laterally distances which are enormously great as compared with the altitudes we scale. This is a psychological point, and I would like to hear somebody who has studied the psychological side of the question give a thorough explanation of it. We think nothing at all of a journey from here to Kalgoorlie, 300 miles, while if a man climbs a hill 300 feet high he thinks he has done quite enough before breakfast; and I think the same principle is carried into all our dealings, and the differences in altitude do not strike us as clearly as do the horizontal extent of various phenomena.

With regard to physiography, it has one great advantage in teaching, and that is that one requires no apparatus and no laboratory. In the first year of work at the University here, when neither laboratories nor apparatus were available, and when we had to start lectures somehow, by hook or by crook, I adopted the method of giving the physiography course at the very outset, and I think this was not without its advantages. The result was considerable interest on the part of quite a large proportion of the students, and they got a very fair grip of the aspects of physiography. We had an excursion after the first term, and I was extremely pleased to find the way in which the students had picked up the essential points of Davis's new science of physiography. We were not able in that year to go on to a detailed study of geology, and the physiography course filled the gap in the curri-
quire for their prosecution laboratory and costly apparatus. Some may say that geology does equally, but I think that the balance of cost and elaborateness will be rather in favour of geology than
culum as far as we were able to fill it. Physics and chemistry re-
quire for their prosecution laboratory and costly apparatus. Some may·say that geology does equally, but I think that the balance of cost and elaborateness will be rather in favour of geology than

against it. Once a student has passed through a training in mineralogy and petrology and has entered the domain of geology proper, the whole world is his laboratory, and he can carry his apparatus in his pocket; so that the prosecution of the study is not a costly one, and it is pre-eminently a subject of which a man can make a hobby, and in which he may go far with very little expense to himself.

I do not wish to claim that geology is the only science that has psychological advantages. Zoology and Botany possess them to an equal extent, but it is somewhat doubtful, I think, whether they touch the every-day work of the engineer on quite so many points as is done by geology, hence there is, I think, a preponderance of advantage in favour of the latter in the training of an engineer.

One more educational advantage of geology lies in the fact that, in it, the student finds many direct applications of the facts and laws he has been learning in chemistry and physics. This re-acts on his interest in those subjects which everybody regards as absolutely essential to the training of the engineer. It affords him good food for thought outside the routine of lectures and laboratory work in those other more essential subjects.

Quite a different sort of advantage may be claimed for geology as a subject during a student's University work in engineering. Most of his work tends to keep him indoors, and the geological excursion is a healthy antidote. This may not be so important a factor in a country like this, where we have such a lot of fresh air and sunshine, and where field sports and compulsory training take a man into the air a great deal, but in other countries, where these advantages, or disadvantages as you may regard them, are not present, it is something to be reckoned with. Another advantage, perhaps not the least of all, is the training students get in our geological camps in the methods of camp life—and you would be surprised to find how ignorant many Western Australian boys are, even of the elements of camp life—and last, but not least, in the virtues of good temper under hardship, unselfishness and good fellowship—qualities which have been very marked indeed in the brief, but happy, intercourse which I have had with students of engineering at the University of Western Australia.

I am afraid that my knowledge of the subject of engineering prevents me from going into very great detail in the subject of the advantages that a study of geology might be, but perhaps, with that as a text, you may be able to advise me whether geology should be taught and if so, in what direction. I may say that, with regard to the training of engineers in geology, I am quite open to hints in any direction, and I shall be very very glad if the engineers of Western Australia will help me in this matter to give a training that is adequate, and at the same time is not excessive, for the students who, later on, will join the ranks of the professional engineer.

THE PLACE OF GEOLOGY IN THE TRAINING OF AN ENGINEER.

Discussion.

Mr. P. V. O'Brien said: I am strongly in favour of Engineers studying Geology, as much as ever they can manage to learn of it. After my experience of the last 20 years of the water supply of the interior of the country I quite agree with the course outlined by Professor Woolnough for students. I do not think an Engineer can get along satisfactorily without a very fair and broad knowledge of Geology. He can get advice, as the Professor says, on any critical questions such as the foundations of a very big work, but a man away out in the interior boring for or conserving water has to make up his mind very often on the ground what he is going to do. A good mining engineer must therefore be a good geologist.

Professor Whitfeld said: I certainly am strongly in favour of the view that every Engineer should have some knowledge of Geology. There must be an immense number of valuable deposits and much valuable data to be collected in nearly one million square miles if the people only had a knowledge of the roughest principles of Geology, so that I think it is doubly essential for the young Engineers of this country, both as Engineers and Citizens of the State, who are likely to travel about the country, that they should know when they are meeting some geological phenomena. They ought to be able to recognise if it is something worth determining. Exact knowledge of a subject like mineralogy requires an immense amount of study. There is another aspect, and that is the educational—the general widening effect of Geology. Both Professor Woolnough and myself were students of Professor David (Sydney University). I do not think anyone who has been under a man of that sort could fail to be tremendously influenced by him. There was the sense of fellowship and the sense of striving for knowledge, for the advancement of the nation or the human race, or whatever you like to call it. Everyone knew that Professor David had by far the best knowledge, I suppose, of anyone, of the coal measures of New South Wales. I know on one excursion we were looking for the outcrop of the Wallsend seam. When Professor David found it, it was simply a little brown streak on the side of a stream, but it was the outcrop of a 20 or 30 foot coal seam. We were all enthusiastic, and he persuaded us to sink a shaft on the bank of this creek to prove really that this was the Wallsend seam. We volunteered to sink the shaft (Professor Woolnough was one of the party). The water came in and we had no appliances and we had to sink this wretched shaft I think about 30 feet or so—a most wonderful-looking shaft. Three or four of us started it,

and we were all very long in the leg and we had the steps going down the shaft about six feet apart. But anyhow we managed to get through this seam, about 4 or 5 feet of coal, at the end of a week. But a thing like that, as I say, has an influence on you.: We were all working really for the love of knowledge and science. There is no doubt Professor David could have turned his knowledge to great monetary advantage, but he did not dream of doing such a thing. He was simply working for the enthusiasm and love of the subject. And that is certainly a widening subject in that way. We had other excursions on the sandstone ranges, and they all created a sort of fellowship and had a broadening effect, I think, on the characters of the students that were there, and in that way I think it is a very valuable subject. As regards the more particular aspect of it in Western Australia, we have problems like the water supply which are very intricate and very important, and I think, as most of our Civil Engineers have something to do with water supply and railways, and the railways depend to a very large extent on water supply, they should have a knowledge of Geology for that reason. In any case it is decidedly important that we should all study this subject, and I think Professor Woolnough with his enthusiasm is likely to do a great deal of good to the young Engineers of this State.

Mr. Light: Professor Woolnough to-night has issued a challenge to the members of this Institution, and I do not think there is any man here in this room that will take up the challenge and try to prove to the Professor that Geology can be separated from Engineering, Civil Engineering in particular. To Railway Civil Engineering Geology is very closely allied, and I should not like to argue with the Professor that it was not. The Professor, in his preliminary remarks, referred to two items, one was the location of the railway through the Mount Lofty ranges in South Australia and the location of the North Coast Railway in New South Wales, and I hoped he would also mention one only 15 miles from Perth. He has probably seen it himself. It is situated between Darlington and Smith's Mill, on what was originally the old main line. I expect he has been up that line, and probably seen it. If he has not seen it I shall be very pleased to take him up any day and show it to him.

Mr. Hillman: I think this Institution should be very grateful to Professor Woolnough for what he has given us. I was pleased to see that Professor Woolnough divided his subject, in so far as training is concerned, into two parts, the general culture which Geology brings to us and the specific applications of it, and more, that he only really presumed to teach the student how to learn after he had commenced his practice. I was particularly interested in the subject of the three dimensions which the Professor said Geology taught. I do not think it is quite realised

how difficult it is to live in three dimensions, and the clear way in which the Professor put that rather appealed to me, as I have had an experience of the same sort, in this way, though my experience led to transition from one dimension to two rather than two to three. I commenced a certain work with a foreman who had been usel to living in one dimension, laying stormwater drains or sewers, and had so far, I found, been living a lineal life from the point of view of supervision, and the work he had to take from me was No. 2—the building of a reservoir—and he was completely fogged; he was still only able to see one dimension, and he was not able to look after things in the area at all. That is not a far-fetched example, and I think it is one that applies in the same way that the Professor's remarks regarding three dimensions do.

Mr. Oldham: I do not rise with any idea at all of accepting the Professor's challenge. I wish, for my part, to thank him for the able way in which he handled the subject. It seems to me that there is not the slightest doubt regarding the necessity for a very good knowledge of Geology for any Engineer in a State like this. On the other hand, I think that the University students can consider themselves very fortunate that they have such a Professor to teach them, and that they have an extensive literature dealing with the geology of Australia. I think they are living in very fortunate times indeed. As the Professor says, it is not a question of an Engineer becoming a high-class Geologist, but it is a matter of his knowing enough of Geology to be able to decide whether he can fix things up for himself or whether it is better for him to get expert advice. The relationship between the two sciences was impressed upon me some few months ago when I had the fortune to visit the interior of Queensland in the company of several eminent Geologists and Engineers, in connection with artesian water in the great artesian basin. It was a most interesting trip, and I may say that a great deal of the geological discussion was lost on me on account of my very slight knowledge of the science, but it was most extremely interesting. I may say that one of the Geologists, wherever we stopped, and we travelled fast and far, nobbled any local resident on the subject of particular classes of stones, native weapons, or any particular local geological feature, and specimens of all sorts. Before we had travelled many miles in the motors we were to some extent lumbered up with these specimens. However, there is no doubt that there is a very great deal in what the Professor has also said regarding the expansion of one's mind through the study of Geology. I also listened with great interest to the remarks made by the Professor concerning the three dimensions. That opens up a very large field of thought. The hope occurred in my mind at the time that the Professor, at any rate,

would be left with us a long time to pursue his wanderings in the horizontal before, in the ordinary steps of nature, he was compelled to take them in the vertical.

MR. LAWSON: I do not know that anyone present to-night wishes to accept the Professor's challenge. For myself, I think he might have gone a little more into the detail of what he considered essential for the Engineer to know. Those who have had anything to do with Hydraulic Engineering must admit that, as far as hydraulic work is concerned, Geology plays a very important part. The paper to-night goes to show how wide and extensive the training of an Engineer must of necessity be, and one can only fully realise this when one has to deal with problems of the ordinary nature. Surface indications do not always, perhaps, point out to the Engineer what he would like, and it is only when he has to solve a problem which the surface does not indicate with the exactness that might be wished, that he realises how important a part Geology plays in Engineering structures. We all know in the construction of a dam, the foundation is the main essential. We also know how easy it is to save or to spend money by a knowledge of the proper place to establish a quarry to get stone that gives the best results for the concrete and for the plumbstones in the wall. We have also the problem of finding sand, whether it is better to crush it from the country rock or to obtain it by bringing it from some other source. For all these things an Engineer is greatly assisted by a knowledge of Geology. We have also the detailed knowledge of Geology which should enter very largely into our road construction. We cannot, and I do not think anyone will wish to, limit the amount of Geology that an Engineer may learn during his course at the University or anywhere else. In regard to the calling in of the specialist, this is also a matter that requires a great deal of consideration. Sometimes, as Mr. O'Brien has pointed out, you have no opportunity of calling in a specialist, but many times it would be desirable to call in a specialist to give information and advice that would be useful, not only for the individual work in progress, but also for future works. We should have at the disposal of every Engineer maps showing the geological features throughout the whole of the State, so that he may be able to see at a glance what class of country, what material is at his disposal in any given district, and if this were done, and done thoroughly, and a map of this nature prepared, it would be of untold value to the State for all time, and it could not be better undertaken than at the present time, when, for many purposes, the Engineering works of this State can only be considered as being in their infancy. In saying this I do not overlook what has been done for the mining industry by our Geological staff. We are very much indebted to Professor Woolnough for his paper to-night.

Mr. Hickson: It has been very interesting to listen to the Professor's address on this very large subject. I do not think there can be any doubt that Geology is of the utmost importance to the Engineer, and I think every day of our lives we are missing some points that, with a little knowledge, would save a very considerable amount of time and money to the State. The principal thing I had in my mind was in the construction of dam banks. We cut a trench and construct a dam at the end of a gully, but we very often assume a great deal as to the holding capacity of that dam. I certainly think that there are many cases where a Geologist would be of the greatest service to us to look over all these sites. One of the biggest difficulties we have in this State is the presence of salt, and there again I do not doubt geological knowledge would very greatly assist us.

Mr. Evans: It seemed to me when the Professor was opening his paper that he addressed us in a somewhat apologetic mode. Now I do not know that there is any apology needed or any reasons wanted to show us that Geology is an absolute necessity. Speaking as a mechanical engineer I must admit that he does not come very closely to myself, but still I, with the others who have spoken, am satisfied that it is an essential feature, and I particularly rose to tell the Professor that, from the student's point of view (I am not speaking for myself, but still I can speak on the point), his lectures, and especially those excursions to which he has made reference, have been of very great value and assistance to his students, and the amount of enthusiasm that I know in two or three cases they have brought to bear, shows that they at least appreciate their Professor and also realise that he is showing and teaching them something that will be of very great benefit to them.

Mr. Edmiston: I must say that the Professor, in his opening remarks, dispelled from my mind perhaps the last doubt I ever entertained as to the value of Geology to the Engineer. I can hardly realise how an Engineer could carry out certain classes of works, such as large water works, weir construction, railway building, and tunnelling, and so on, without some knowledge of Geology. I was very interested, however, in the other aspect of the subject which the Professor put before us, viz., that embellishing quality which a knowledge of such a science as Geology must have. I think that most Engineers will admit that the bare knowledge of purely Engineering itself does not add a very elegant or embellishing quality to us, and certainly I think that the subject of Geology, together with some of the other sciences, does add a quality to a man which is very frequently on the surface and which is very charming, and I am sorry to say that Engineering does not seem to me to lend that quality to us. I was interested also in the Professor's remarks with regard to a third dimension. It just occurred to my mind that with all our

knowledge we live very much on the surface, even on the surface of the things that you know. I am very grateful to the Professor for his very able paper.

MR. KERSLAKE: I certainly think that the Professor's method—Physiography first—is best. I studied in England. Physiography there is a very easy part of Geology to learn. You have all your sedimentary beds from the latest to the oldest, and most of my training was Physiography, and recently I had brought under my notice an instance where Geological knowledge to an Engineer was of immense value. There was a high cliff which was always subject to land slips. Revetment works and retaining walls had been tried, but proved too expensive. A good Engineer was employed, who was also a Geologist. He found that the cliff was really quicksands, alternating with clay beds, which caused the whole cliff to slide. He drove a tunnel into the cliff, and, crosscutting the end, drained the cliff. Since then there have been no more slips.

MR. HAYNES: Before the Professor makes his reply I should like to say a word or two. I feel quite sure that if any of us had any doubt at all about the necessity for the study of Geology by Engineers in their course of training, the Professor has successfully removed that doubt. It makes one almost wish they had been born many years later in life than some of us have. I do not remember that I had very much instruction in Geology in my more youthful days. I certainly did have told me at least that in all cuttings we were to be careful to make the side slope against the lay of the strata rather than the other way, and we were told that if we could we must make provision against slips. There was no reason given—simply the statement of the fact. We were also instructed, of course, that all stones in masonry should be laid upon their natural bed, because if we did not they would shale off under the weight, but how we were to discover the natural bed did not transpire at all. It was generally left to the stone worker—the mason. Now that is one point that I was going to say I should like to hear the Professor on, though I realise that the subject is so big he would have to give us quite another lecture, and he entered upon this one with such marked enthusiasm that I am rather tempted to think he may do that. It is easy enough to know the bed of a sedimentary rock, but when you come to a block of diorite, for example, it is not quite as easy to the untrained. Without doubt there is a very close association, close relation, between the Geologist and the Engineer, and the Professor was pointing out, very properly I suppose, from his point of view the immense importance of Geology to the Engineer, and he made what we might call a safeguarding excuse by saying he did not know very much about Engineering. I venture to say that if he had he would have remembered that Geology owes a very great deal to the Engineer—a very great

deal. The Engineer, in the course of his works, has excavated deep cuttings, etc., which have disclosed the formation of strata of the ground, and in many such ways, not to speak about the mining industry. The Professor asked whether it should be taught, and, if so, in what direction? I feel quite sure that every Engineer will readily admit that it ought to be taught. Our supreme regret is that that fact was not discovered in our more youthful days. In what direction should it be taught? Well, I hardly know enough about it to venture to say, but I will tell you what we want to know; what the Engineer wants to know is something about foundations. He wants to know their carrying capacity; he wants to know something about the movement of water through sand; what is known as the cone of depression in a pump well; permeability and the disintegration of various types of rocks and similar or kindred substances; he wants to know, too, something about quarrying and such other things. Indeed, there is no doubt about it that an Engineer wants to know, he needs to know, the structure of the earth upon which he is about to put the foundation for, say, a reservoir, the reservoir wall, the bridge pier, and I venture almost to believe it might be useful in the case of docks, too, because we know quite well that the success or failure of many Engineering—in fact all Engineering works—depends very much upon their foundation. Sometimes enormous expense is gone to in the matter of putting foundations down in order, as the builder says, that he may err on the safe side. There is one intance which came under my notice, and it was this: It happened in this town, in connection with the celebrated refuse destructor a little way from here. The Council of the day, having determined to build that, called by advertisement for competitive designs, but each contractor was to submit his own, and the chimney shaft that was to be built was, I think, 90 feet high, and one contractor, who was an Engineer, designed the foundation to be, I think, 30ft. square. It was to be close-piled; the piles were to be filled in with concrete in the usual way. However, none of these were accepted, and the responsibility happened to be thrown upon me to get over the difficulty. The foundation upon which the stack, 120ft. high, stands, is just 18ft. square and 5ft. thick of concrete, no piles or anything of that kind, and it did not sink more than $\frac{1}{8}$ of an inch. It was built upon purely white sand, which carried water in the winter time. That is to say, if you excavated now you would probably find water within 4ft. of the surface, certainly it would be so in the latter part of the winter. I do not claim any particular virtue for that, but mention incidentally the amount of expense, somewhere about £800 or £900, which was saved, not due to my special knowledge of Geology, but to a general knowledge of this particular locality. We quite agree that it is essential that a study of this subject should, like all others, commence at the very beginning, but then those who are older cannot do that, and I quite

believe, if the information could be made available to us who are older, so that we too could use it, I am quite certain that we would take a great deal of interest in following it out, for, without doubt, there can be nothing more charming, I should say, than a study of Geology. Indeed, it was the subtle humour of the Professor I liked as much as anything in his lecture when he spoke of it as really being a recreation, that is, to the Engineer, after the Engineer has had a long course of study which is necessarily somewhat exact, and, as he suggests, produces some narrowness of view, in which, however, I do not agree with him. I want to say I think the Engineer is a very broad-minded creature, nothing narrow about him. However, it was put as rather a recreation, there was that social element in it, and the companionship.

Professor Woolnough: I am very grateful to you for the way in which you have received me to-night, and I am relieved to find that the opinion of the meeting, either through charity or through conviction, is strongly in favour of a certain amount of geological training for Engineers. The question has been raised as to the amount of that, and my thesis is that, unless you can give an Engineer enough training in any subject to enable him to go on further, you had better leave that subject out altogether. Either give him enough to be of use or let him spend the time on something else, and that is the one question, the one point, on which I wanted information from you, whether you thought it was worth while spending a fair amount of time, as is necessary in the first year, for a complete course of Engineering. Unless that is done I would far prefer to see the subject cut right out altogether. The President has mentioned the desirability of knowing about foundations, about water movement, permeability of strata, the weathering capacities, and so on. I maintain that these are rather the applications of Geology, and that, in order to obtain any real knowledge with regard to them, it is necessary to have the first principles of the subject, and I very strongly maintain the desirability of teaching an Engineer in his first year (I am speaking entirely of the Engineers who pass through the University) not what the direct applications of Geology to his subject are, but teaching him the methods by means of which he can go on and make those direct applications himself. If a man has a thoroughly sound elementary knowledge of the various branches of Geology he is in a position to take up these specialised subjects, and to take them up from the point of view of the Engineer, with sufficient geological knowledge to guarantee that he will not get off the track and make any serious mistakes from lack of geological knowledge. I do not attempt in the first year course to teach Engineers the applications of the subject at all. That is a point which I think a good many students fail to realise, and a good many students are apt to feel that their Geology course is entirely wasted because so little direct notice is taken of these immediate applications to Engineering practice. But I think I can claim

that I keep this in view all the way through the teaching work of the course, and that the students who have passed through that course and done pretty well in it are in a position to make these applications themselves.

The debt of the Geologist to the Engineer I am very glad to do my share towards paying. One cannot but realise that without the Engineer many of the most important problems of Geology would still be awaiting settlement. Artificial excavations made in various places have been of the utmost possible value, and in places have been absolutely indispensable in the working out of the geological structure of the Continent on a broad scale.

Mr. Oldham mentioned the fact that a 20 years course would be necessary to enable an Engineer to learn all he ought to know about the various sciences, but that is just the one point on which I beg to differ from him. It is not, in my opinion, essential for a man in his University course to do more than learn how to learn. When we have turned out a man from the University with the Hall Mark of the University on him, we do not by any means say that he is fit to take an Engineering position. All we say is, to the best of our ability, we have taught him how to learn the work that deals with his special branch in life afterwards, and if we have done that I think it is worth two, three, or four years of a young man's life to have picked up these methods of thought and study that are so essential to the successful carrying out of his life's work afterwards.

Both Mr. Oldham and the Chairman have referred to travelling with Geologists. Take my advice and never travel with a Geologist. He is more bother than he is worth on an expedition. As Mr. Oldham says, he has a lot of fossils, and they are always so awkward, generally sharp-edged, and he generally manages to drop a heavy hammer on your toe or something of that kind, particularly if you are travelling by motor car, because there is nothing more aggravating in a motor journey than to be pulled up at all sorts of odd times and awkward places, any little sand patch and steep hill where the Geologist wants to get out and take something which catches his eye. He is a man of roving eye. The typical Geologist ought to have his eyes working on swivels—one working in each direction; and if you are in a hurry he is sure to find something that will keep him there for a long time.

As Professor Whitfeld has said, some of us have had experience of travelling with Professor David, and although, in his younger days at all events, it was a very difficult matter for anybody with shorter legs than Professor Whitfeld to keep him in sight at all, there were occasions when at anything between 3 and 4 o'clock in the afternoon we had had nothing to eat since 7 o'clock in the morning. We sometimes blessed his enthusiasm to work out a problem before he got home.

I am extremely grateful to Mr. Evans for the kind remarks he made with regard to the work amongst the students. I must say, since I came to Western Australia, I have had nothing but kindness at the hands of my students. I know I am a little bit of a crank myself on the subject of Geology, and all the way through what I have to say you must remember that I am an enthusiast and I am pleading for my own subject, but I hope you will agree with some of the main premises at all events. But if I am enthusiastic I must say that my students have been extremely good to me in the matter of enthusiasm, and they have humoured me as far as reasonable under the circumstances. I know that on several occasions they have even gone hungry for quite a considerable time after they ought to have had their lunches, and on more than one occasion when I have run them short of provisions they have been quite content to live on one slice of bread per meal and no grumbling about it. And on every occasion the students of the University of Western Australia have shown themselves thoroughly men throughout, and I am quite sure that the qualities which these men show are not lessened by the University Course, and will be of the utmost value to them and to the community when they take their place in the ranks of the Engineers in this State.

With regard to Mr. Light's question, I have never yet been out of the train at Smith's Mill. I have passed over that spot two or three times, and have always recognised it as an extremely interesting spot. The structure which has developed there is an extremely interesting one, and of very high importance to the geological history of the State. The phenomenon is not by any means confined to the spot between Darlington and Smith's Mill, but is widespread throughout the Darling Range area. That immense mass of white clay that has developed on the railway line there and has caused such a bad foundation for the railway line represents an old land surface formed at a time incalculable, long ago when the surface of Western Australia stood for ages and ages at a height very little above sea level. It represents a most peculiar combination of circumstances in the land surface, resulting in the dissolving out from the granite the insoluble constituents leaving only the soluble behind. They have formed the ubiquitous ironstone capping of these hills about Perth and all through Western Australia. The white clay you find almost universally under this ironstone represents the completely leached and dissolved portion of the original granite surface. This can only have taken place, as I say, through the land being of very low relief, from insignificant hills and valleys being developed and standing at a low altitude, and also shows that the climatic conditions that exist at the present time when we have a very markedly wet winter and dry summer, must have existed in those far

distant ages past when the pipe clays like those of Smith's Mill, Baker's Hill, etc., were formed and the ironstone cappings were formed on top of them.

I thank you very much, gentlemen. for the kind way in which you have received this attempt of mine to justify the teaching of Geology, and for the encouraging remarks passed with regard to the subject as a portion of the training for the future Engineers of Western Australia.

RAILWAY OPERATIONS.

By G. W. Stead.

General.—Railway operations are as complex as they are interesting, and, owing to the various conditions which prevail in different countries, such as topography, density of population, nature of industries, production, etc., whilst this statement applies to passenger as well as goods traffic, there are several differences. It is generally true to say that the volume of passenger traffic between any two places will balance itself, whereas in the transportation of goods, the major portion of the traffic is in one direction, and in consequence the return trains must run with empties or decreased loads, and this is to a great extent more pronounced in this State than in any other State in Australia. Except during the wheat season ,nearly the whole of the traffic is in the down direction, this being accounted for by the sparsely populated districts through which the railways run being without factories or industries.

Common Carriers.—The business of a railway is to carry both passengers and goods, and as such is what is termed a common carrier. There are two kinds of carriers under the law: special carriers and common carriers. The legal liability of the two vary and are different. A special carrier is, in a sense, an occasional carrier, and therefore he may legally carry on whatever terms and conditions he chooses to impose upon his customer, and to which his customer may choose to agree. If the distinction ended here many complications would be avoided. It happens, however, that common carriers convert themselves for particular goods into special carriers, and it is here where disputes arise in respect to liabilities as to whether the carrier in a particular transaction was a "special" or "common" carrier. A common carrier is indicated by the word "common," and carrier commonly for any person, and hence he is a common carrier. It frequently happens that there are two alternate rates, known as "O.R." and "C.R." The consignor, to obtain advantage of the "owner's risk" rates, consigns his goods accordingly, and by so doing accepts the risk. If anything should go amiss with the goods he prefers a claim, and because it is not paid he generally complains of the tyranny of the railways in not paying his claim. forgetting that he had the alternative of sending his goods at "company's risk." It should be generally understood that when goods are carried at "owner's risk" the sender must be prepared to accept the risk, as it is only when wilful negligence is proved that a claim can succeed when goods are so consigned.

Organisations.—For the conduct of the business, the staff organisation is on the following lines:—General Manager, responsible for the safe and economical management of the railway,

machinery, and all things appertaining thereto; Engineer for Permanent Way and Works, responsible for the maintenance of ways and works, including buildings, etc.; the Mechanical Engineer, responsible for power and rolling stock; and the Transportation Department, for the business arrangements, neither of which are separate organisations, but are all brought together always under one man, and in this respect is similar to an army corps division and brigade, each composed of different elements but each under one commander.

In America, and on some of the lines in England, the officer in charge of a district is not only in charge of his own particular department, but in charge of the entire undertaking; in other words, he is the general manager so far as his own particular district is concerned. He has under him district engineers, locomotive inspectors and transportation inspectors, and in this way the district superintendent is supported by the experience and advice of men who are actually carrying out the operations, and the officers themselves obtain some acquaintance with each other's business.

In the selection of officers for the position of district superintendent, the choice is not confined to any particular branch of the service, but the man who is most likely to succeed is appointed. Officers holding these positions are given a free hand, and the policy of most managments is to say: "Do as you please, but get the best results and do not make too many mistakes"; in other words, put the load on the man and change him if he is unsuitable.

Transportation.—In referring to transportation, I am not dealing alone with what is known in this State as the traffic branch, but the whole of the operating staff—the largest force of the railway—and on its economical administration depends to a very large extent the success or failure of the undertaking. The work of the transportation department is to provide the engines, and the necessary service, to carry both passengers and goods with reasonable despatch. In dealing with transportation generally, it will, perhaps, not be out of place to point out some of the transportation difficulties which will arise in this State within the next few years. If we go back to the year 1895 it will be found that the total wheat production of this State amounted only to 520,000 bushels, while for the years 1913/1914 the yield had increased to 15,000,000 bushels, approximately. I am firmly of the opinion that, given normal seasons, our wheat yield will not be less than 50,000,000 bushels within the next ten years. To convey 50,000,000 bushels of wheat by rail is not such a huge undertaking, providing it can be distributed over each month of the year. Unfortunately, these favorable conditions do not prevail, but rather it is expected that practically the whole of the season's wheat yield should be conveyed in three

to four months at the outside. To transport 50,000,000 bushels of wheat would, under these conditions, I estimate, require 165,432 trucks such as we have in this State, which is equal to 4,354 trains, or an average of 48 trains per day; the dead weight of the trucks previously referred to would be equal to 827,660 tons. If this wheat was conveyed in wagons of 35 tons capacity the number required would be reduced to 39,683, and the tare 476,196 tons, showing a reduction of unprofitable haulage of 351,464 tons; in other words, the wheat would be transported with 660 less trains than if the small capacity wagons were in use. Perhaps the following figures, which are official, will more fully demonstrate my point: In 1903 the average car in use on the Canadian-Pacific had a tare of 16 tons and carrying capacity of 26 tons; in 1908 the average tare was 17 tons and the capacity 29½ tons; in 1913 the average tare was 18.3 tons, whilst the capacity had gone up to 34.8 tons, showing an increase of 14.2 per cent. in tare and an increase in carrying capacity of 33.3 per cent. The statistics further show that the average weight of contents for 1913 was 20.16 tons, and for 1915 23.15 tons; the average size of train in 1913 consisted of 19 loaded and 6 empties, and in 1915 18 loaded and 5 empties. If we take the effect of these figures on the total traffic we find that the saving in loco. mileage amounted to 898,630 for the year. I think that these figures are sufficiently convincing to show the necessity for larger capacity wagons. The Argentine railways in 1908 transported 140,000,000 bushels of wheat. These railways are mostly owned by British companies, who continued the old practice adopted on British railways of using the small capacity wagon, with the result that they were quite unable to carry the wheat to the seaboard with anything like reasonable despatch, the old wheat being frequently left at the inland stations when the new crop was gathered. Owing, no doubt, to adverse criticism, the companies had to adopt the high carrying capacity wagons, and the result has been more than satisfactory to both farmers, shippers and the railway companies themselves. The wagon generally in use on the Argentine railways has a carrying capacity of 35 to 50 tons.

Loading of Trains.—All that has made the low rates of goods in America profitable has been secured by increasing the carrying capacity of wagons and the hauling power of engines. When the bogie truck was first invented its great value was realised in America, and it gradually displaced the four-wheeled truck until now very few of the latter are in use. Several tests have been made, and the practical lesson learnt from these tests prove: first, that it is the number of vehicles in a train which is the important factor in governing the load which the engine can haul. The more the load is concentrated—that is to say, the fewer the vehicles in which the load is placed—the smaller, proportionally, will be the draw-bar pull, and the greater the

load which the engine can haul without increased strain or expense; consequently, an improvement in the proportion between the tare and carrying capacity of a vehicle is not sufficient. It is the number of vehicles carrying the load which requires to be reduced for the best results to be produced. Secondly, the tonnage basis of computing the load does not ensure the engine being worked to its full capacity, and that the draw-bar pull is the correct basis of computation. In some tests made in America, both practical and theoretical, it has been ascertained that if the load of three 17-ton wagons is concentrated in one 51-ton wagon, there is not only a saving in the dead weight haul, but there is a saving of over 43 per cent. in the demand on the engine, and the engine can haul 53 per cent. more of paying load without any increased effort or expense. It would be seen, therefore, that the best results can only be obtained by concentrating the load in as few vehicles as possible. It is, however, little use to have engines and wagons capable of hauling heavy trains unless full advantage is taken of the power available. It is the duty of the transportation branch to see that trains are fully loaded, and it is just as necessary for the locomotive branch to provide suitable engines for the class of train to be worked. Goods trains are liable to cancellation and alteration as the business warrants, and unless there is a complete system of ascertaining the freight to be moved, full advantage cannot be taken of the power. To enable controlling officers to regulate the trains it is customary for stations to furnish, at certain hours throughout the day, the the train arrangements are made. Where the traffic is mostly in one direction the train loading returns should show an average tonnage for both up and down transit, and from this information of not less than 96 per cent. of the engine capacity.

Loading of Trucks.—This is just as important as the loading of trains, and if good results are to be obtained, each loading station must forward a return every week to the supervising officer, giving the individual number of each truck loaded, the class of goods and weight of contents. If these returns are watched carefully from week to week it will be at once seen if the necessary care and attention is paid to the loading of wagons.

Train Mileage.—This is the unit used by the majority of English companies for measuring both the revenue and expenditure. In my opinion, however, the train mileage does not furnish the management with the necessary details as to whether he is obtaining the best results. I will deal further with this subject when referring to statistics.

Distribution of Rolling Stock.—I think I am quite safe in saying that during the busy season there is no other subject demanding such close attention as the efficient distribution of rolling stock. In Australia we have lines practically without any station staff and yet a very large number of sidings, each requisitioning

for wagons. It will readily be seen that where you have resident officers it is a very easy matter to distribute wagons, but totally different where there is no resident staff and where the information has to be obtained from quite unreliable sources. Certainly there are times when it is not practicable to supply the whole of the wagons requisitioned for, as no administration can be expected to meet all demands during a very busy season. This could only be done by having a large proportion of your rolling stock standing idle for seven or eight months during the year, and it is only necessary to mention that as each ten-ton truck costs approximately £160, and management would not be justified in keeping stock standing idle for eight months of the year. The system of distribution of rolling stock is on the following lines:—At a certain time each day, mostly after 5 p.m.—that is after the day's loading has been completed—the station master telegraphs to the distributing office full particulars of all rolling stock on hand, either loaded or empty, and his requirements for the following day's use. At the same time that he furnishes his own station's return, he endeavors as far as practicable to also give the same information with regard to the unattended sidings under his control. The distributing office, on receipt of this information, summarises the whole of the station returns, and from this makes out his distributing list as to the movements of the empties and loaded wagons and the trains by which they are to be moved. The importance of this work cannot be underestimated, for on it depends the result to be obtained from the following day's loading and the avoidance of unnecessary haulage of empty wagons. To see empty wagons hauled in opposite directions shows most wasteful management.

Wagon Mileage.—To ascertain if the rolling stock has been utilised to the best advantage, some check must be kept upon the movements. For this purpose each guard in charge of a train prepares what is known as a wagon and tonnage return, on which the number, destination of wagon, contents, weight and mileage hauled are recorded. This return is summarised each day, and it can be seen at any time the mileage that the truck has made. From this return any delays that have occurred can be immediately traced. At the end of the month it is possible to ascertain the total mileage the whole of the stock has made during the month, and if the average mileage is from 26 to 28 daily it will be shown that fair results have been obtained on the 3ft. 6in. gauge line.

Marshalling of Trains.—The system of making up trains by shunting engines in an overcrowded and quite unsuitable yard is not only wasteful, but results in serious delays to trains in starting from depot stations, which in turn disorganises other trains. I had the opportunity of inspecting the work done in a gravitation yard, where all traffic from the dock stations in Liverpool was hauled to Edgehill and there sorted by gravitation.

The train was hauled into what is known as the "arrival roads," the engine detached and returned immediately to one of the dock stations for another load, and before its return the previous load had been sorted and gone forward to its destination.

The whole system of marshalling and making up a train is designed to permit of the work being done with the least amount of effort and in the quickest possible time, and a train can be got ready to go out in less than ten minutes' time without the use of any engine.

Loading of Goods.—I do not know if any of the gentlemen present have ever been in a large railway receiving goods shed after the carts and lorries have finished unloading their goods, and the shed platform covered from end to end with merchandise of every kind, going to every station in the country: can you wonder if, by some means, goods for, say, Tenindewa are placed in the same truck as goods for some other station of a similar name? The work of checking and loading wagons can only be gained by long experience, as it frequently happens that goods for perhaps ten, fifteen or twenty stations is loaded in the same truck, which must be loaded in station order, so that the guard may be able to distribute the goods at the various stations while the train waits. The work of way-billing is another important duty, as upon the prompt despatch of invoices depends the quick and correct delivery of goods. Of recent years a great improvement has been made in this direction. The use of a typewriter for this work has made it possible to complete the invoice in duplicate, and the delivery sheet for the destination station at the same time, thus saving the delay in having to take press copies of the invoices after completion.

System of Working.—The means by which trains can be moved in safety between different points depends upon the close observation of all signals, proper and efficient signalling, and some token of authority to be held by drivers when working on single lines. The working of single lines is generally achieved by either the staff or ticket system, electric staff tablet, Winter single line block, and in America by what is known as the "train despatcher" system. Briefly, the staff and ticket system consists of two staff boxes, two books of tickets, and mostly a wooden staff with the names of the stations between which it is available engraved on a brass plate secured to the staff. The driver must have for his authority to proceed through the section the staff or a ticket. This staff is the key by which the box containing the tickets can be opened. The necessity to make use of the staff tickets does not arise unless there are two trains going in the same direction before a train is coming in the opposite direction, and in this case the driver of the first train would be hande da ticket by the signalman, who, on seeing the staff, would be authorised to proceed through the section It happens, however,

in practice, owing to the late running of trains, that the staff would be found to be at the wrong end of the section and there being no means to transfer that staff to the station where the train is already waiting. With the co-operaion of the signalmen at both ends of the section, and the authority of the superintendent of the district, the train is worked forward on wha tis known as a "line clear" report. The signalman who has possession of the staff certifies that the staff is locked up and will be kept secured until the train arrives with the "line clear" report. Strictly speaking, this is an infringement of the staff and ticket system, but with long sections such as we have in Australia it has been found impracticable to transfer the staff without causing serious inconvenience to the travelling public. There, however, can be no question that the issue of "line clear" reports should be reduced to a minimum, and should these "line clear" reports occsur frequently, rather than take any risk the staff and ticket system should be superseded by either the electric staff or tablet.

Electrc Staff.—This supersedes the train staff and ticket and consists of two columns, each containing twelve to sixteen staves, and one column at each end of the section. Briefly, the electric staff system is to prevent more than one train being between two staff sections at the same time, and when no train is in the section, to admit of a train being started from either end. This is accomplished by every train carrying a staff. It will therefore be seen at once that so long as the section is not already occupied a train can be started from either end, and this dispenses with the necessity of "line clear" reports. In certain cases where the traffic is heavy and the sections long it has been found necessary to introduce what is known as "permissive" block working. In such cases the locking of the electric staff instrument is so arranged that the staff can be divided into two or three parts, which will permit of the same number of trains following each other and by this means will increase the carrying capacity of the line. It, however, is not possible to obtain another staff from the opposite end of the section until the whole of the divided parts have been received by the station in advance.

Bank Engine Key.—When necessary, in the interest of economy, to use bank engines over certain points of the line, the engine would only be required to assist the train for a short distance in the advanced section. In such cases the electric staff is so arranged and fitted with what is known as a bank engine key, which authorises the driver of the bank engine to return to the station in the rear, without going through the section, so that by this means you have the train proceeding in the one direction whilst the bank engine is returning to the station to where he obtained the bank engine key, but until both the staff held by the driver of the train engine and the key held by the bank engine are placed in the instruments at both end sof the section, no other staff can be obtained.

TYERS' ELECTRIC TABLET.—This system is in almost all respects similar to the electric staff, with the exception that instead of a staff a round metal token is used. Messrs. Tyers and Co. have introduced what is known as an absolute or permissive tablet instrument, the object of which is to facilitate the crossing of trains at unattended sidings. As an example: a section of 20 miles in length, the running time for a goods train is 70 minutes, an unattended siding exists 10 miles from either end, there are trains at both ends of the section ready to proceed in opposite directions; it therefore follows that the ordinary staff working either one or the other of the trains must be delayed for 70 minutes, but with Tyers' intermediate crossing instrument neither of the trains would be delayed, as the crossing could be made at the intermediate siding. At each end of the section there are two instruments, one known as the control and the other known as the secondary. The control instrument is fitted with an electrically locked hopper, in which is placed the tablet withdrawn from the ordinary tablet instrument and which when inserted and locked in the hopper of the control instrument switches the crossing instrument in circuit and enables the signalman at each end of the section to take out a crossing tablet for the intermediate siding. The trains on arriving at the intermediate siding would exchange the crossing tablet and until both trains had arrived at their respective ends of the section, and the tablet had been deposited in the control instrument, it would not be possible to obtain another tablet at either end.

DOUBLE LINE WORKING.—The working of double lines of railway also require o be divided into sections; the lengths of same will entirely depend upon the density of the traffic. There is this difference between the working of a single and double railway, and that is that the driver, while working upon a single line railway, is always in possession of some token, whilst on double lines he has to be entirely guided by the signals. To maintain a space between each train what is known as block instruments are provided. Instruments for block working may be placed in one or two divisions. In the first, the indicating apparatus is stabled in either of the positions, it can take up the current transient and is only used to effect a change of position; in the other division, the indicating apparatus is stabled in one position only and change of position from the normal can only be maintained by a continuous current. Instrumets of the first division indicate two conditions only, i.e., "line blocked" (normal position), "line clear" and "train on line." The difference just shown may seem to be of little importance, but in reality is is of the utmost importance to indicate the exact position of affairs at any stage of block working. "Line clear" with instruments of the first division indicates that there is no train in the section to which the instrument refers. With instruments of the second division it not only indicates that there is no train in the section,

but also that the signalman at the receiving end has given permission for the train to be sent forward. The Winter block instrument is the only instrument in this State which belongs to the first division. Syke's Lock and Block.—This instrument belongs to the second division, previously referred to, and is in use in this State, and does not only give all usual signals, but also locks the block instrument with the outdoor mechanical signals, to control the starting or advance starting signals, at the sending end of the section by the signalman at the receiving end. The system provides a combined locking and indicating instrument for each line of rails, each instrument being provided with a separate line wire, separate bell communication between the ends of each section by which all signals other than those indicating the condition of the line for the time being are sent, a mercury contact rail treadle placed near the starter or advanced signal to release the locking arrangements at the proper time, an automatic signal arm replacer fixed on the signal, which is also worked with the treadle. From this it will be seen that this object of signalling is to take out of the hands of the signalman the power of giving "line clear" to the rear station until the train has cleared the treadle at his starting signal.

With the Winter instrument the entire responsibility is cast upon the signalman of giving "line clear," whilst with the lock and block it is not possible to give "line clear" to the station in the rear whilst there is a train in the section.

Automatic Signalling.—Of these systems there are many, but as I have only seen one of these systems in use I can only speak of one, and that is the Westinghouse electric pneumatic. This system employs a track circuit which is operated by a battery at one end and a relay at the other, the current being carried through the rails, which are connected together through the joints by specially prepared wires. When a train or a vehicle enters a block section, the wheels short-circuit the current, which causes the signal protecting the section to assume the danger position and to remain in that position so long as there are a pair of wheels in that section.

The signals are operated by compressed air, which requires the provision of a power house at intervals of about 25 miles. I had the opportunity of inspecting this system on one of the tube railways in London, and was much impressed with it. At Whitechapel I took particular notice of what is known as an illuminated diagram by which the signalman could see the movements of trains in three different sections. Whilst there is a train in any of the sections the diagram is dark, but immediately the train clears a section the diagram is illuminated. On the tube railways they also have what is known as a "train stop," which is in such a position as to apply the brake and bring the train to a stand, should a train by accident over-run the signals.

Whilst on the subject of track circuits, it is worthy to mention

that quite recently two trains collided a Binalong, in New South Wales. This accident was caused owing to the signals for a line already occupied being pulled off in error. Had a system of track locking been in force at Binalong this accident could not have happened. This in itself should warrant the track locking of all crossing loops on single lines where the traffic was of any importance.

SIGNALLING AND INTERLOCKING.—Block instruments themselves are of very little use without the aid of outdoor signals to guide the train men, and in English practice the following signals are in use, i.e., "distant," "home starting" and "advanced starting," "stop" or "directing" and "siding" signals.

The positions are as follows.—"Distant," a hundred to a thousand yards outside home; "home" signals to protect the station or any points leading to the main line; "starting" signals, ahead of the station, and "advanced starting" signals in advance of the starter. The space between "home starting" and "advanced starting" is generally governed by the length of trains. The points when interlocked are so arranged that the signals cannot be pulled off unless the points are set for the road for which the signal applies. The signals are worked from the frame by wires. To secure facing points in their proper position they must be bolted by a locking plunger passing through the stretcher bar and to prevent the signalman drawing the bolt while a train is passing over the points they must be fitted with a locking bar to suit the longest wheel base of the rolling stock. The first step towards the interlocking of points and signals is the concentration of the levers in one frame. Briefly, the interlocking of points and signals must be so arranged that a signal cannot be lowered for a train until the points have been properly set and locked; that any two signals which might lead to a collision cannot be exhibited at the same time; and that after signals have been lowered for a train to pass, no points connected with or leading to the line on which the train is running can be moved.

Detectors should be fitted in order to ensure that the points are properly set before the signals are lowered, and to discover any failure in the connections between the levers and points; otherwise if the roads were buckled a lever might be pulled over without any corresponding movement of the points. The general requirements of a good interlocking apparatus are that there shall be very close locking, i.e., the locking shall not be effected until the stroke has been completed; and that the apparatus shall not only be effective in working, but strong and simple in construction.

STATISTICS.—Some form of statistical measurement of receipts has probably been in use since the very beginning of railway working. There are still people who distrust average figures and the old grumble of red tape when statistics are mentioned. As a matter of fact, red tape is nothing more or less than honest

system; an objection to it betrays the casual man's dislike of order and regularity and his fondness for rule of thumb methods and rough ideas. Perhaps no feature of railway operations, unless it be that of rates and fares, has given rise to more discussion than that of the use of statistical units for the control of train working. Whatever system be used the object is the same. A railway is usually said to manufacture and sell transportation, and, like any other manufacturer, requires to know the cost of what is sold in order to measure efficiency. The train-mile is the basis most generally used, especially in England. Certainly the train-mile is a more reliable unit than the ratio of expenditure, and it is not sufficient to dismiss it as unpractical in face of the fact that the majority of the managers of railways in Great Britain maintain their faith in its reliability. At the same time, it is defective as a unit. The railway sells transport and receives its earnings in return for certain weight a certain distance. The defect of the train-mile is that it is not a complete figure. The train may consist of five wagons or fifty wagons, and may convey goods of the third class or coal. An improvement—for example, the better loading of wagons—might show an increased cost per mile, since the expenditure would be divided by fewer train-miles. The train-mile is a variable unit, and does not represent the same combination of conditions at different periods and in different places. What is required is a unit which shall represent the work done, not in running a train of unknown composition, but in carrying a given weight a known distance, and this we have in the ton-mile; or, for passenger traffic, the passenger-mile. Ton mileage is the total of the ton carried one mile. It provides a unit comprehending the two factors of the transport sold; that is to say, weight lifted and distance conveyed. Moreover, the ton-mile is the basis of many other average figures, such as loading, per wagon per train, receipt, length of haul, etc., all of which are useful. It is not altogether the value of the ton-mile itself that has warranted its preparation, but the other units which form a part of it, or which are derivable from it and which cannot be produced without it. There are many other definitions of the ton-mile. It is necessary to understand the nature and use for this unit. All the following units are formed from the ton and passenger mileage:—

Number of ton-miles.
Passenger-miles.
Average train loads.
Average wagon loads.
Number of passengers per train.
Number of passengers per coach.
Length of haul—goods.
Length of journey—passengers.
Average rate per ton-mile.
Average rate per passenger per mile.

Passenger Mileage.—The passenger-mile is one passenger carried one mile, and the computation of passenger mileage is similar to that of ton mileage. Ten passengers booking to a station ten miles distant are equal to 100 passenger-miles.

Railways and War.—The present struggle has demonstrated the great advantage to any country possessing strategic railways over those less favored. It has enabled Germany to concentrate her troops either on the eastern or western frontiers in marvellously quick time, but not only this: it has enabled her to move troops to any position that may be threatened, or to any position where the defence is weak, not only troops, but munitions, etc.

It is claimed by the Germans that on mobilisation no fewer than 26,000 trains were required to transport 2,000,000 men, with horses, stores, munitions of war, etc. In England, on mobilisation, it is stated that 1,500 trains were necessary, and one day 213 troop trains arrived at different parts. It is not known the exact number of men, but it may be roughly estimated at 150,000, in addition to which there were 60,000 horses, 6,000 vehicles and 5,000 tons of luggage. Up to the end of September the English railway companies ran 2,200 specials for troops alone.

The necessity for strategic railways in Australia is beyond question one of the greatest importansce. What would happen if we were suddenly attacked on this coast, or in the Northern Territory, with our present railways? So far as can be seen, the defence of Perth would not be of the slightest use against a foe like Germany, and, once let them get a footing and cut off our food and ammunition supply, our position would be desperate, as we rely upon the coast and the Eastern States for our existence. Even with the Trans-Continental open, and change of gauge at two or three points, it would be a very slow process of getting either men or equipment from East to West. Again, the Trans-Continental is so close to the coast that it could be cut quite easily. In my opinion, a direct railway from Fremantle to Cunnamulla, in Queensland, from which connections should be made to Melbourne, in Victoria, to Condobolin and Bourke, in New South Wales, and from Thallon, in Queensland; and a direct line from Oodnadatta, in South Australia, to Port Darwin, with connections from the main trans-Continental, so that troops from the eastern coast could be transported to either the western or northern coasts. It is, however, essential that the gauge should be uniform.

RAILWAY OPERATIONS.

Discussion.

Mr. Haynes: Mr. Stead's paper is full of interest. It is what we might describe as an appeal to the commercial side of engineering, given to us by a keen business man, who speaks from experience. The paper is full of interesting figures and details, and I have every confidence in assuring Mr. Stead that we thoroughly appreciate it. I am glad to see so many railway men present, and leave to them the honour of opening the discussion.

Mr. Evans: Mr. Stead said that he thought that most of the railwaymen of Western Australia were in favour of the train mile. Now, as a locomotive officer, I can assure him that he is absolutely wrong. I am out and out an advocate of the ton mile, and particularly from the traction point of view. For instance, it will be obvious that if the locomotive branch, which supplies the power, is to be paid on the train mile system, or be called to account for what it does on the train mile system, the smaller the engines we can put on the better result the locomotive will show, but as locomotive men we know that our duty, is to hook on to the biggest load the Traffic Department can give us. With concentrated and extensive engine power, we can get cheaper haulage, and furthermore, do not occupy the section any longer with a big load than with a small load, and further would only be running with one driver, fireman and guard. It seems to me that it should not be peculiar to the locomotive branch alone that the ton mile should have greater prominence than it has. I believe Mr. Stead will admit that there are difficulties in the ton mile in the amount of statistics that have to be obtained. At least, that is what I have always understood from the Traffic Department; but if this discussion can bring forward something which will enable us to get the ton mile instead of the train mile, as a locomotive man then I shall be very thankful. It is what we are looking for, and I am sure that it is the correct thing. It is very largely used in America, where they have some very big propositions to deal with. I have read recently that the new Manager-in-Chief of the Great Eastern Railway in England, is an American. At a recent meeting he admitted that he did not think anything nad ever been done better in the world in railway work than the mobolisation of the troops by the English companies, and that is why I am a firm believer in the ton mile, and I would like to see it brought into effect here, because not only would it be to the advantage of the locomotive branch, the branch supplying the power, but as Mr. Stead has pointed out, it would give such information that you can touch the spot every time.

Mr. Stead: The Great Eastern has introduced the ton mile Mr. Thornton is the manager's name.

Mr. Lawson: There is one feature that probably Mr. Stead can supply, and that is in regard to the 35 ton trucks on the Canadian railways. Mr. Stead dealt more particularly with these, I take it, with regard to the handling of wheat, but I gather from what I have read on this matter, nearly all these trucks are used in connection with bulk handling. Most of the American traffic in wheat has been found to be most profitable where the grain is handled in bulk, and therefore I take it that these large trucks are nearly all used in the way of dumping trucks, or trucks that are emptied rapidly by some method such as the grain elevator. The ton mile seems to be, if I might say so, the only rational way of keeping record of the traffic, but no doubt, as Mr. Evans has pointed out, it entails a good deal of statistical work.

Mr. Gardam: The point that struck me most in the paper was the omission of any reference to the importance of electrical operation of railways. In reference more particularly to passenger traffic, the advantages of electric operation stand out very prominently, and will become more important in the future. The principal advantage of electrical operation is probably to be found in suburban working. Trains composed of a more or less fixed number of coaches are running at times filled to their limit, and the rest of the day are practicaly empty, which does not lead to efficiency in haulage power or the use of rolling stock, whereas if we adopt electrical operation for service of that class we can arrange the size of the train to suit, and we need only use the necessary power for the number of passengers at that time. In big terminal stations, there is the question of handling the trains and shunting, which can be more effectively done, and at a very considerably reduced cost in the case of electrically operated trains. Speaking of electrification of railways as a whole, although the lines electrically equipped are increasing in length everywhere, while the main advantages have undoubtedly been proved in short and suburban services, for long distance trains the electrical operation is more a matter of finance than practicability.

ELECTRICITY GENERATION AND SUPPLY.

By W. H. Taylor.

The subject which I have taken, viz., Electricity Generation and Supply, is one which has engaged the Engineers of the Electrical profession at home to exercise their greatest skill in bringing the art to the high pitch it has risen to-day. The particular portion of England which I have taken as an example, and the most progressive, is that known as the North-East Coast.

This portion extends from Blyth in thê North to Gresborough in the South, and to Bankfoot and Consett in the West; the area is, approximately, 1,000 square miles. As some indication of the industries emhbraced in this area the table below will give some idea of the proportion, to the remainder of the Unuited Kingdom:

Table No 1.

——	Population at Census, 1911.	Coal Mined, 1913. Tons.	Coke Made, 1913. Tons.	Ironstone Mined, 1913. Tons.	Pig Iron Made, 1913. Tons.	Shipping Built, 1913. Tonnage.
N.E. Coast Industrial Area ..	2,300,000	56,352,218	7,500,000	6,010,836	3,869,214	625,289
United Kingdom ..	45,211,888	287,430,473	20,529,732	15,997,328	10,260,315	1,231,921
Ratio: N.E. Coast / United Kingdon	5·1%	19·6%	36·5%	37·5%	37·7%	51·0%

To build 51 per cent. of the total tonnage of the United Kingdom on two rivers, the Tyne and the Weir, calls for large engineering shops in addition to the ship-building slipways.

Besides ship-building, the coal and iron industries have a good percentage of the total output for these products of the United Kingdom. The developments which have taken place are largely due to the fact that cheap electrical power is available in any quantity and in any place.

The growth from 1900 to 1914 was 5,000 H.P. to 300,000 H.P. in connected load to the supply companies' mains. The lighting supply had only increased from 5,000 to 20,000 H.P., against 5,000 to 300,000 H.P. for traction, power and heating, collieries, iron mines and bulk supplies. This emphasises the fact that power has been the lines on which the development of the company has been made.

The combined output from all stations on the system on December 18, 1914, was approximately 74,000 kilowatts or 110,000 electrical horse power, while the maximum load is 74,000 kilowatts and the minimum 40,000 kilowatts at 1.30 a.m., the maximum occurring at 4.30 p.m. I am not permitted to give the actual figures of the companies' output, but I can say it is over 400,000,000 units per annum.

Commencement of Power Supply on the N.E. Coast.

The power supply business is in the hands of the Newcastle Electric Supply and distributing companies, who commenced operations in quite a small way with 1,800 kilowatts of plant, which has now grown to 157,000 kilowatts, or 210,000 horse power.

The Newcastle Supply Co.'s first station was situated at Pandon Dene in the City of Newcastle, and started about 1889. In the year 1900 the company began to extend its field of action, with the result that a new station had to be built. It was apparent that the correct place was the river and a site was selected at Neptune Bank on Tyne. Here the birth of what was afterwards to be the largest power supply company in the United Kingdom saw the light of day. A station having a capacity of 6,800 H.P. (5,100 K.W.) was erected. Developments were rapid, and the companies' engineers were faced with the problem of further extensions. The point at issue was, is Neptune Bank Station suitable to become the central power station of the company, with an ultimate capacity of tens of thousands of kilowatts? or should a new station be built and designed to handle such power? The last was the decision arrived at. The companies' engineers were certain that if reciprocating engines were installed, the size of the unit would be limited, due to site space conditions. The largest reciprocating engine that was running was at the companies' Neptune Bank Station, 1,500 kilowatts. At this time the Hon. C. A. Parsons was pressing forward his claims for the steam turbine, which up to this time had not been used commercially to any extent for large generating sets. To gain experience and to test under actual operating conditions of power station work a 2,000 kilowatt set was ordered and installed at Neptune Bank. The good results obtained decided the engineers that the prime mover for the new station was the turbine. A suitable site was chosen close to Neptune Bank Station at Carville on Tyne, work was commenced and the new station put into operation in July, 1904, four years after the company launched out in power supply earnestly. This station was the first of its kind to be laid down exclusively for bulk supply and driven by turbines only. The first sets to be installed were two 2,000 kilowatt and two 5,000 kilowatt, a total of 14,000 kilowatts. These 5,000 K.W. sets were the largest in commercial use at the time, their normal capacity being 7,000 electrical H.P. One of these turbines ran for 7,500 hours, during which time it was only

out of commission for 52 hours. The steam pressure used is 200lbs. per sq. inch, 150deg. F. superheat and 95 per cent. vacuum, or 28½ inches of mercury with 30-inch barometer. The steam consumption of these sets proved to be 15lbs. per kilowatt hour.

These sets generate three-phase 40 cycle current at 5,750 volts, the turbines running at 1,200 revolutions per minute. The boiler house was equipped with Babcock and Wilcox marine type boilers. This station from the modest 14,000 kilowatt has now increased to 64,000 kilowatts or 83,000 electrical horse power.

The particular feature of the Carville power station was the introduction of the independent unit system, the first instance in which it was adopted in England. At the time great failures were predicted in the system. Instead of proving as prophesied, a failure, it proved the soundness of the arguments for its adoption. Each independent unit consisted of:

Steam turbine and generator
Boilers
Economisers
Transformer
Air pump motor
Circulating pump motor
Economiser motor
Induced draught fan
Stoker motors
Ash conveyor
Main oil switch
Isolating switches and bus bars in duplicate.

The lay out was so arranged that each unit could be coupled up in parallel on the steam and electrical side; it was not necesrasy to have separate banks of boilers, the isolation being made by means of valves in the main steam header.

To deal with the power for which this station was designed, the usual methods of switchgear arrangement then existing were quite inadequate. The rule usually adopted in selecting generator oil switches was to select those capable of carrying the necessary current and insulated for the working pressure. This was seen to be the wrong lines on which to design the main oil switches for such a system, and the following basis was established: In the event of a faulty generator, the whole plant running will feed back through the generator switch, and on its opening will be called upon to break the short circuit current of the stations; perhaps ten times normal full load of the machines. A switch designed on the current-carrying basis of the machine to which it was connected would fail miserably at its first opening under short circuit conditions. This was foreseen, and the generator and feeder switches designed to open the full short circuit current of the station; the switch-gear installed will clear a fault of

40,000 kilowatts of plant on the bus bars with certainty. The question of switch-gear in large power stations is of paramount importance, and too much attention cannot possibly be given to its design and arrangement.

To eliminate chances of failure each phase should be enclosed in a concrete cell or compartment, except in certain instances where the oil switches for high voltages are specially designed to be installed as open units. A bus bar fault is the worst form that can develop, being as it would close up to the generator, with the result that the full power of the station on short circuit is spending its energy with disastrous results. To make such an occurrence an impossibility, no instrument transformers are permitted on the bus bar side of the oil switch. When the switch opens the bus bars are then free of any apparatus that can cause trouble to the system. The same arrangements are made in the case of the feeder circuits.

The switchboard in the engine room controls the generators only. All feeder circuits are operated from the control room. Arrangements are also being made to control the generators from this position.

The steady growth of the company and the enormous cable system, when considering further additions to the generating capacity, led the engineers to consider erecting another power station near the centre of the supply to eliminate the duplication of feeders to deal with the growing demands for power. Another reason for this policy, apart from the desirability of having two stations on so large a system, was to give security of supply. A site was chosen at Dunstan-on-Tyne of approximately 30½ acres in extent. The station generates three-phase current at a periodicity of 40 cycles and a normal pressure of 5,750 volts. The steam pressure is 200lbs. per square inch, and is superheated to a total temperature of 570deg. F. The station is laid out to accommodate six generating sets, each of 8,000 K.W. normal capacity and 10,000 K.W. maximum capacity or a total of 50,000 kilowatts. The present plant consists of two A.E.G. Impulse turbines, each of 8,000 K.W. capacity at 1,200 R.P.M., of the three-bearing type and one Richardson-Westgarth Brown Boveri set of 7,500 K.W. capacity at 1,200 R.P.M. The first machines have given considerable trouble due to balance, whereas the English turbine set has run from the start with the greatest satisfaction to the company. The above-mentioned set was a new departure in English practice, as in this case the high pressure Parson element was separate from the low. This was decided upon in view of the excessive length of one spindle, at the same time by having two separate cylinders it was possible to run with very much finer clearances at the high pressure end, consequently a more

economical unit. An extension set has been installed of 15,000 K.W.; for this the disc and drum principle was adopted. The boiler house is set at right angles to the turbine room, consequently reducing the whole size of the building, besides making a more economical pipework layout. The following is the present boiler house equipment:

No. boilers: 8.
Type· Babcock and Wilcox Marine.
Heating surface: 6,725 sq. ft.
Heating superheater: 1,156 sq. ft.
Type of grates. Chain.
Grate area: 168 sq. ft.
Economiser heating surface: 2,880 sq. ft.
Draught: Induced.
Steam pressure: 200lbs. per sq. inch.
Evaporation normal: 30,000lbs.
Evaporation: 37,500lbs.

Switchgear.

The switchgear controlling the generators is situated in a switch-house 150 yards from the turbine room. Here the main oil switches, bus bars and feeders are grouped. From the generator cables are run to the switch-house for connecting the generators to the bus bars. In the turbine room, except for the auxiliaries there is no electrical gear visible.

In the control room a telephone installation is installed connected to the system control room at Carville. Here the Engineer-in-Charge can receive working instructions from the system engineer, as to the plant to run and what load to carry. Each generator's main oil switch will carry continuously 20,000 K.W. and will open under any conditions. The bus bars are divided by a sectionising switch of 30,000 K.W. capacity. In Dunstan, as Carville, nothing in the way of current limiting reactance have been installed, the generators and feeders being protected by means of balanced protective gear of the Merz-Price type.

Space does not permit of my going into the utilisation of waste heat, as this would form an interesting paper for discussion alone. It is sufficient to state that out of a total of 210,500 H.P. of generating station capacity 45,000 H.P. is generated entirely without the use of coal fired boilers.

NORTH-EAST COAST POWER COMPANIES.

PARTICULARS OF GENERATING STATIONS.

(ALL 3-PHASE, 40 CYCLES.)

Power Station.	Type.	Horse-Power of Generating Plant.	Voltage.
1. Carville	Coal-fired	* 83,000	5,750
2. Dunston ...	Coal-fired and Gas ...	46,000	5,750
3. Philadelphia ...	Coal-fired	† 24,000	5,750
4. Neptune Bank ...	Coal-fired	6,800	5,750
5. Hebburn ..	Coal-fired	4,300	5,750
6. Blaydon	Waste Heat and Gas ..	3,200	5,750
7. Bankfoot ...	Waste Heat and Gas ...	5,300	3,000
8. Bowden Close ...	Waste Heat and Gas ...	6,700	3,000
9. Grangetown ...	Coal-fired and Waste Heat	8,000	11,500
10. Newport ...	Waste Heat	7,300	2,750
11. Weardale ...	Waste Heat and Coal-fired	5,300	2,750
12. Clarence ...	Waste Heat	3,200	2,750
13. Ayresome ..	Waste Heat	3,200	2,750
14. Tees Bridge ...	Waste Heat	1,600	2,750
15. Shotton	Waste Heat	1,300	2,750
16. Horden	Waste Heat	1,300	2,750
	Total	210,500	

*Includes 31,000 h.p. now being installed.
† ,, 13,000 ,, ,, ,,

MERZ & McLELLAN,
January, 1915.

Out of 42,000,000 units in 1914, 16,000,000 were generated by waste heat, or 38.1 per cent. of the total output. As the waste heat utilisation is now being developed, in the near future we may expect to see more plants erected. I would mention that no gas engines have been installed, all generating units being turbines. Until some decided step in gas engine or gas turbine development has taken place the engineers will pursue the steam policy only from the consideration of reliability on a large system, subject to heavy overloads and shocks, which the turbine is highly suited to take care of.

TRANSMISSION SYSTEM.

Current is generated at Carville and Dunstan at 5,750 volts, and supplied into the main distributing system in and around the Tyne. Underground cables are used for the supply to the various substations, and overhead lines on the main transmission system in Cleveland and Durham, also in the North as far as Blyth. The pressure for transmission is stepped up from 5,750 to 20,000 volts in static substations.

On the greater portion of the line wood poles are used of A construction, carrying single and double circuits at 5,750 to 20,000 volts. There are several lines having steel towers and "K"

tubular poles. The standard spacing is 80 yards, using poles 40 feet high. Pin type insulators with galvanised mild steel pins mounted on channel iron cross arms is standard practice. At terminals in the more recent lines disc suspension strain insulators have been adopted. These lend themselves easier to connect to cable dividing boxes.

Earthing and Lightning.

In recent years the use of horn gap and aluminium electrolytic arresters have been discarded, where it is possible to terminate a transmission line in a length of underground cable. It was proved that horn gap arresters, likewise multigap arresters, were responsible for many transformer failures due to oscillation set up by the discharges across the spark gaps. To prevent this an underground cable introduced at each end would offer sufficient resistance to protect the transformers. This system was adopted several years ago with excellent results. In the case of overhead lines terminating at the substation overhead, aluminium lightning arresters have been to some extent used.

To ensure a satisfactory earth connection a continuous earth wire is carried the entire length of the line, and connected to an earth plate at every fifth pole. This has been done to ensure the instant operation of protective devices installed, to protect the lines against short circuits to earth.

The system operates with the centre point of the generators earthed, one generator only being earthed through a resistance at each power station.

Cable System Protection.

The underground feeders are protected by balanced protective gear on both the 5,750 and 20,000 volt side.

Without the development of the balanced protective gear it would have been impossible to operate such an extensive system coupled solid, as used on the N.E. Coast. A word of explanation may not be out of place in its description. It is dependent on the principle that if a certain current enters a cable at one end and the same current leaves at the other, the cable is sound; if not, it is obvious there is a fault in its length. To utilise this principle current transformers are connected to each phase and the secondaries opposed. When the circuit is unbalanced a current will circulate in the current transformers secondary windings, which are connected to a relay which operates the trip on the main oil switch. So reliable is the apparatus that faulty generators and feeders carrying thousands of kilowatts have been disconnected from the system without shock. The author has repeatedly short-circuited bus bars with an earth feeder to test such apparatus without injurious effects to seam turbine plants of large capacity. The utmost confidence has been placed in the apparatus and has proved beyond doubt all that was claimed for

it. A modification has been introduced in the split conductor system which eliminates the use of a pilot wire, thereby reducing the initial expenditure. It has been found in practice that the system is to be relied upon quite as much as the Merz-Price system using pilot wires.

Consumers.

The consumers taking current from the Company range from the domestic supply to that of railways, tramways and municipalities grouped under the following headings:—

Consumer.	Load.
N.E. Railway Company.	Electric Suburban Railways
Tramways	Street Cars
Shipbuilding	Motors
Engine Works	Motors
Ordnance Works	Motors
Flour Mills	Motors
Rope Works	Motors
Docks	Pumping
Chemical	United Alkalid Co.
Electro Flex Co.	Electric Steel Furnaces
Middlesborough Corporation	Bulk Supply
Tynemouth Corporation	Bulk Supply
Durham Corporation	Bulk Supply
Cleveland & Durham Co.	Bulk Supply
Collieries	Electric Winches & Coal Cutters
Steel Works	Rolling Mills
Iron Furnaces	Charging Gear
Domestic Supply	Lighting, Heating & Cooking

Total Connected Load, 300,000 H.P.
Maximum Load on Station, 100,000 H.P.
Load Factor, 61.5 per cent.

Reasons for Bulk Supply System.

The reason for the development of Electricity on Tyneside has been due to the combination of the system. Had the power supply been in the hands of small generating stations instead of two large ones, owned by the company, the present stage could not have been reached. Current is sold on a commercial basis by the companies' engineers. They set out a scheme for one power supply, and by such have now the extensive system of mains all over the North-East Coast. To obtain low generating costs and a cheap supply of power it is obvious that one and only one factor can govern the cost of production, that is the "Load Factor" on the station. To illustrate this I will cite the case of one individual who commences work at 8 a.m. He will rise at 6.30, have a breakfast cooked by electricity, at 7 a.m. he is conveyed to his employment by electric car or train, his plant will be driven by electric motors, he will return by car or train and have his evening

meal cooked electrically; in the evening he will have his amusements largely electrically, pictures or theatres, if he stays at home he will use electric light. From a power house engineers point all these things could not take place at one time, but if you give a portion to each generating station then it will be seen that when the man is cooking his morning meal the tramways or train load is light, and so on. If all are combined in one power house then results similar to those of the Newcastle Electric Supply Company are certain to be achieved.

The large consumers, such as Sir Armstrong Whitworth and Co., the United Alkali, Wallsend Slipway, North-East Railway and hundreds of others, were not prompted in any way by sentiment to take bulk supplies, but that they could obtain current cheaper than they themselves can generate on loads which would give good load factors. It may be said that two stations could have turbines of equal steam consumption, but without the exact same conditions their costs cannot be the same.

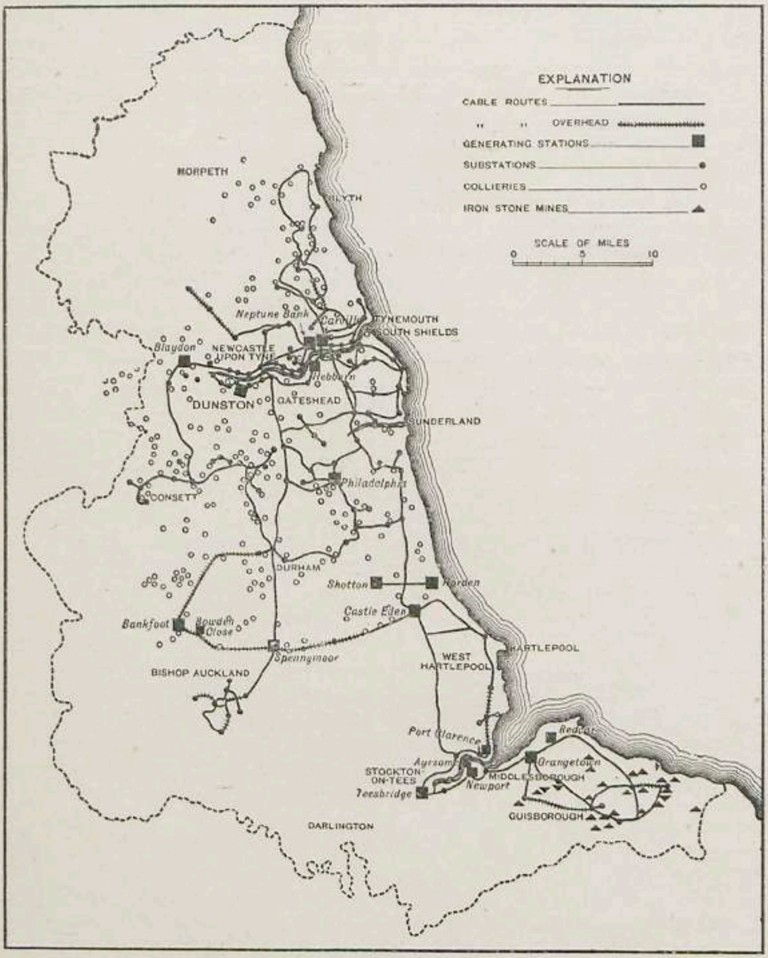
ELECTRICITY GENERATION AND SUPPLY

Discussion.

Mr. Lawson: Gentlemen, I am sure we have all listened with great pleasure to Mr. Taylor's paper to-night. He has taken us altogether away from local engineering, but yet it brings to our mind, a paper that we had some time ago here by Mr. Edmiston on the question of establishing the power stations of the Metropolis at Collie. It does not seem very far away—100 miles—when we see the large area which is dealt with by this one company in England. This particular combine or trust seems to have had an entire monopoly in the district in which it has worked, and moreover it seems to be particularly fortunate in having a district where there is not much waste heat available for power users, but, it is of great interest to us to see what can be done in the lines of long transmission. There is another thing which appear to us, namely the difference between a commercially run plant in the class of buildings and poles put up compared with what we are putting up in and around Perth. The sub-power stations in the Old Country do not compare altogether favourably from an architectural point of view with what we are erecting in and around Perth, and if they were putting up the same stations now they would probably put them up more on the lines on which we are putting them up here. I am sure we are deeply indebted to Mr. Taylor for the paper.

Mr. Broadbent: The subject itself appeals to me very much indeed, especially this North-East coast generating station. I had the pleasure about 18 months ago of seeing the reality of the appliances that Mr. Taylor has been good enough to show on the slides to-night. Mr. Taylor has displayed a great deal of thought in his paper. When we have time to look at the whole scheme we shall be able to discuss this paper. There are no figures as regards running costs there, so there is not much to pull to pieces.

Mr. Taylor: I am sure it has been quite as much interest to myself as it has been to you, but the trouble in connection with a subject of that kind is to confine oneself to detail. I could have given you costs and figures which would have set the place in an uproar, but just at the present moment, in view of certain conditions in and around the City, I do not think it is advisable.



The North-East Coast Power System.

ARBORICULTURE AND ITS RELATION TO MUNICIPAL ENGINEERING.

By H. C. Castilla.

In matters connected with all work of the Engineers, general recognition should be given to two main factors, or perhaps one factor with two adjuncts, viz., efficiency, with which should go hand in hand with economy and health.

To the ordinary observer the idea that Arboriculture should have any bearing in this respect on Municipal Engineering may appear whimsical, and even to the Engineer, who has not made municipal work a study, it may appear far-fetched. and yet from my own somewhat limited observation I am convinced that a very strong case may be made out for the proper planting of trees, not only in streets but also in gardens adjacent to them. I have consulted numerous text-books on the subject of Municipal Engineering, but beyond mere passing references to tree-planting, in none of them have I found any importance attached to the proper selection of trees owing to their effect on works.

At the outset I must confess myself largely ignorant of Arboriculture, but as an observer and Engineer I am convinced that greater attention should be given to this art in its relation to Municipalities and more especially by the Engineer. As a rule the Engineer trusts to the civic gardener to select the tree, and that official does so, as a rule, regardless of the bearing on Works or even of Health. I am aware that the ideas I am expressing will be scouted. and regarded by many as absurd, but I think I will at least convince my hearers that the subject is worthy of study.

A short time ago I had a conversation with a gentleman on the subject of Arboriculture. he being an authority on the subject, and sought his advice as to the most suitable trees. We did not agree, as I could not induce him to consider my side of it. to wit, the Engineering, and the strongest argument he could adduce was that it was not done in Victoria, a fact of which I was perfectly aware, for I know of no place where mis-selection in tree-planting is, or was, in greater evidence than in the suburbs of Melbourne, and, so far as I can hear, in the country towns of Victoria generally. This matter is receiving greater attention now, but at one time the mischief done by unfit trees must have been incalculable.

The objects of tree-planting in our streets are twofold—decorative and for shade, the latter being superfluous in winter, if not unhealthy. I contend that in our narrower streets, at any rate, the tree should be deciduous, not merely on the score of health to the individual, but also to the road and footway, which require

sun in winter and shade in summer. As to the human being: There is an Italian proverb which says, "Where the sun cannot penetrate the physician will," and the non-deciduous tree has a way of keeping sun and light out of our houses to the detriment of health. "Absurd!" I can imagine some people saying, and yet is there not reason in it? And again, just at the time of the year when the sun should be playing on our roads and footways the evergreen tree prevents it to their detriment, as the friction occasioned by traffic, combined with unevaporated moisture causes undue attrition.

So much for the effect on health of both humans and roads.

A difficulty now arises as to the selection of trees which are deciduous and non-destructive.

At this juncture it may be asked Why is any tree destructive and why a deciduous tree in contradistinction to an evergreen? The answer is that both may be lateral and almost surface rooted, and the object of the Municipal Engineer should be to get a tree which seeks its nourishment at depth, so as to avoid the bursting up of roads, footways, drain pipes, gas pipes, house foundations, etc. Notable instances of the lateral-rooted tree are Cape lilac and Morton Bay fig. In regard to the latter we have not many in evidence here, though two in a garden adjoining the street in which I live at Claremont have raised huge ribs in the footway. In the suburbs of Melbourne, however, they were very much in evidence. The City Surveyor of Melbourne, Mr. Mountain, showed me the doorstep of his house, a heavy granite one, which had been forced about two inches up by the roots of one of these trees planted nearly 40 feet away.

The conclusion I have come to it that the non-deciduous tree should be neglected by the Municipal Engineer, except in cases where there is plenty of room, a second St. Kilda Road, in short, where such evergreens as the red-flowering gum, on account of its great beauty and also that it can be kept low without detriment. The continuous lopping of so many street trees must be in evidence to you all, owing to their interference with cables, to need any comment from me, and therefore attention should be given also to trees with a reasonable height limit.

Now comes the selection of the suitable tree, and this lends itself to investigation, as, although I have been an observer for some considerable time, I lack technical knowlesge on Arboriculture.

When in office in Perth, on the advice of Mr. Feakes, Government gardener, I largely used the acacia, and they are now much in evidence in the east of Wellington and Murray Streets. The results are undoubtedly good. They are very ornamental, deli-

cately coloured, are not too high, shady in summer, tap-rooted, and occasion little scavenging, an important point on which I have not hitherto touched.

For the same reasons, except that of scavenging, the plane tree is much to be commended in many respects. This tree is better than the acacia, it goes deep for nourishment, is tap-rooted, in short, does not rob surrounding gardens. Often I have heard complaints by garden enthusiasts as to why their hedges are failures, and could scarcely induce them to believe it was owing to the planting of our native gums in the streets. A neighbour of mine whose garden is his hobby tested my statements on this point by digging a trench where his hedge failures occurred, and proved the cause beyond all doubt. This is exasperating and unnecessary, and prevents private efforts in the beautification of our suburbs.

In conclusion, I must apologise for the non-technical nature of this sketch, but believe it to be important, and beg to commend it principally to the consideration of those of our profession who specialise in Municipal Engineering, who, although they need not be botanists, ought to be in a position to rule what class of trees should be planted, not only in the streets but contiguous thereto.

ARBORICULTURE AND ITS RELATION TO MUNICIPAL ENGINEERING.

Discussion.

Mr. Haynes: This subject is more important possibly than most of us are disposed to think because it does not come under the review of a great many of our members. There can be no doubt to those who have studied the question that street tree planting has a very great bearing upon the health of any City where it is. Mr. Castilla did no more than introduce the subject, and it is doubtful whether we have sufficient members here to exhaust it, but I should just like to say that it needs to be pointed out that one of the great advantages of trees to my mind is as we all know that while they give off oxygen which we want they consume the carbonic acid which we give off, and they certainly tend very much, to my mind, to elevate the tone of health of any thickly populated area. I do not altogether agree with Mr. Castilla on the question that we ought to adopt deciduous trees in every case except in very wide streets, because of the difficulty in getting suitable trees, and also because of the enormous mess they make, and moreover during our long dry summer and comparatively short winter, this year excluded, we require trees that are evergreen. I quite agree with him about the destruction of our footpaths and roads, but taking it as a whole I think that a study of the subject in this State, and application of it to our towns would be a very distinct advantage. America makes a very special study of it, probably more than any other country. Certainly in Europe they enlarge on it very well indeed. In America they lay great stress on the importance of universal street tree planting. It is unfortunate, I think, that the cities of Western Australia have not adopted it to any very great extent so far as I know. They do not seem to have taken on to it with that seriousness which its importance demands. I have very great pleasure in asking you to accord a vote of thanks to Mr. Castilla for his introduction.

Mr. Farrar: Speaking of tree planting, I have in my mind an avenue of plane trees which I believe exists in the Northern end of King William Street, Adelaide, at the inter-section of North Terrace towards the City bridge. Those trees were very beautiful, but generally came out in the spring time, were a lovely green and very shady, but they had this unfortunate weakness, the first north wind, and they get north winds in Adelaide, that came along, you would see almost the whole of those trees devoid of leaves. They will not stand the fierce heat of what we might call semi-tropical climate, otherwise I think they are very beautiful, but as for planting trees in St. George's Terrace, excepting perhaps the western end of it, personally I think that a mistake in a City. Of course they do destroy the footpaths, but apart from that in a business thoroughfare, I think you want clear

vision of what is going on on both sides of the road. A large avenue, such as is proposed, in the western end of St. George's Terrace, where there are many private residences, does not matter much, but when that portion of St. George's Terrace becomes a business thoroughfare, as it undoubtedly will in the course of a few years, trees will be a mistake. Personally, although they are very beautiful, I think they interfere with the vision. You want a clear view of the street.

Mr. Fraenkel: Inside a town there may be difficulties, but in the streets leading to a town I think there ought to be trees, and I cannot see why not plant fruit trees. There is another reason, because you can rent these trees to people living along the road and get your money back again. If you travel in Germany, the moment you get into Saxony you see every road planted with trees, every kind of tree, but all of them fruit trees, rented out to the people on the road, starting at 1/- and going up to 5/-, and Municipality gets a good bit of money out of it. They certainly make the roads very beautiful, and the men who rent these trees sell the fruit to the wayfarer. If you travel along a road in Saxony you can go into any house on the road and ask to pick fruit for an hour. That perhaps costs 6d. It certainly gives a view to the street which I have never seen anywhere else, and it should be very nice and shady in the summer time when we are riding along the roads here to get a bit of shade and not these dusty roads we have got.

Mr. Castilla: I have very little further to add in addition to what I have said. I should have included some remarks, I suppose with regard to the effect upon consumption of carbonic acid gas. As regards the planting of fruit trees in the streets, I remember at one time there used to be numerous mulberry trees in the streets of Perth, but the little boys made sad havoc. They may be in Saxony, and I know they are also in Japan, but they are well disciplined people in those places. We would have to be a generation or two older in Australia.

End of Volume 6.

Western Australian Institution of Engineers.

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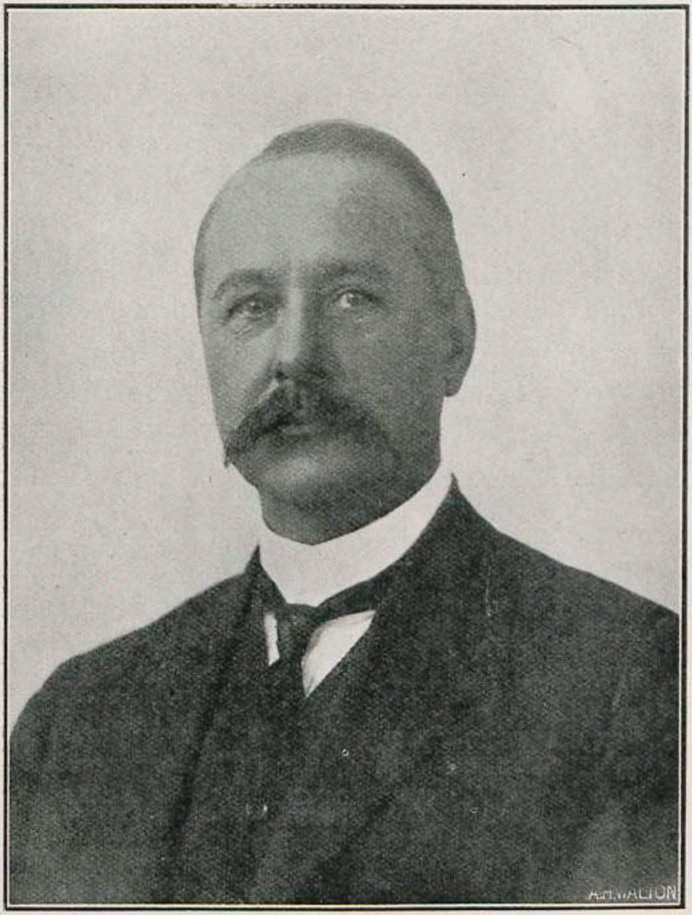


E. A. EVANS, A.M.I.C.E.,
President, 1916-1917.

Mr. EVANS, on his election as President, delivered his presidential address, the subject being "Shells."

PROCEEDINGS—WESTERN AUSTRALIAN INSTITUTION OF ENGINEERS.

PAPERS AND DISCUSSIONS.

POWER FACTOR AND ITS EFFECTS UPON ELECTRICALLY SUPPLIED SYSTEMS.

By WILLIAM H. TAYLOR.

It would be difficult to find any A.C. supply system that does not suffer from the effect of low power factor. A low power factor is a source of worry to the operating engineer, besides a loss financially to the undertaking.

Before setting out on the subject of power factor it may be worth discussing, what is meant by the term used to define the conditions brought about by inductive apparatus connected to the system. We will assume that the E.M.F. and current conform to a sine law for the purpose of this discussion.

Then, when in phase, the current and E.M.F. will rise to a maximum, fall, reverse and rise to a maximum in the opposite direction. At the same time, under the above conditions the product of volts and amperes will represent true watts. Usually the current will lag behind the voltage, then the product of amperes and volts will not represent true watts. The power factor in this case is then less than Unity. A wattmeter would register true watts, the readings of an ammeter and voltmeter apparent watts. To define, and obtain the power factor of a circuit the following procedure could be adopted:

Connect an ammeter, voltmeter and wattmeter in circuit and take the following readings—

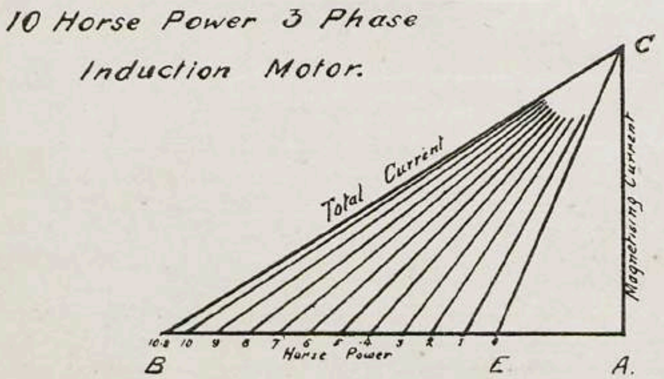
I. Reading=amperes x volts=apparent watts.
II. Reading=wattmeter =true watts.

$$\text{Power Factor} = \frac{\text{True watts}}{\text{Apparent watts.}}$$

The power factor is also defined as the cosine of the angle of lag or lead of the current. As circuits invariably suffer from lagging power factor these only will be discussed.

What is the cause of the current being out of phase with the pressure? The answer is: inductive apparatus and particularly induction motors.

The reasons governing the power factor of an induction motor will be followed more clearly by reference to the following diagram, which is, and can be found in any text-book dealing with alternating current.



Curve A.

Let the line BA represent the true power in K.W., BC the K.V.A. input of the motor, and AC the wattless componant. The portion AE represents the actual power required to drive the motor at no load without pulley belts or attachments.

The power factor is the cosine of the angle of lag, in this case represented by the angle AEC.

Assuming the full load conditions are those given by the length of AD, the $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ loads will be given by the full lines drawn from the point C. When the no load conditions are reached, i.e., the point E, the angle has now become nearly a right angle, therefore a very low power factor results.

The line AC, which is the wattless componant, and being constant, is the magnetising current for the stator. This is at right angles to the true power, and therefore, the greater this quantity becomes, due to air gap, speed and other factors in the design of the motor, the lower the power factor must necessarily be, as this increases the angle ABC.

From the foregoing it is apparent that a plain induction motor must have a very low power factor at light load.

On a supply system the load generally consists of small motors ranging from 5 to 25 horse power, the mean would be about 10

H.P. As these are used on loads having a low load factor, generally not in excess of 50 per cent., it is obvious that for the greater portion of the day the power factor of the system must be low.

The average figure, where the load is large, and made up of small motors, will not exceed .75 and a maximum of .8.

At first, it may appear I have given a low figure, but from experience these are about the usual conditions on a large system. The effect which such would have on a power plant is given in the following example:

Power Factor on System, .75.
Actual Load on Plant, 3,380 K.W.
Apparent Kilowatts, 4,500.

To carry the above load a 4,500 K.V.A. turbine set would be required, whereas at Unity power factor a 3,800 K.V.A. set would suffice.

The above must not be taken as an absolute condition, because it may happen, and does on large systems, that one or two alternators are run to supply the wattless current due to the size of the plant units installed in the power house.

If it became necessary to instal a further unit in the power station at, for example, £30,000, because a spare unit is not available on the peak load, the question of low power factor would then be very vividly brought before the notice of the parties providing the money. The additional expenditure necessary capitalised at 10 per cent. would represent an increased annual charge of £3,000 per annum. This sum would represent the financial effect of a low power factor on this particular generating plant. If the sum required for plant to provide wattless current could have been put into the undertaking profitably and earned 10 per cent. instead of losing 10 per cent., then the management would have considered the expenditure wisely incurred. Not only is the power plant the sufferer, but the distributing system is equally affected, and usually costs more before satisfaction is given to the consumer.

To carry a given kilowatt capacity at .75 power factor, the current increase is 35 per cent. above that at Unity Power Factor, and if the same voltage regulation is to be maintained, additional cables would be necessary. To commence duplicating feeders and distributors is at all times an expensive procedure, more especially where these are laid underground, and where expensive street reinstatements have to be carried out. I know of cases where to reinstate, including the excavation and the laying of the cables, has cost the Department £1 5s. per yard of trench through the suburbs of large cities. A simple calculation serves to bring out the effect on the cable system. For example, we will assume a load of 1,500 kilowatts is to be supplied 2.5 miles from the power station at 6,600 volts with a 2½ per cent. drop at full load.

Cable Required to Supply Load at .75 P.F.–

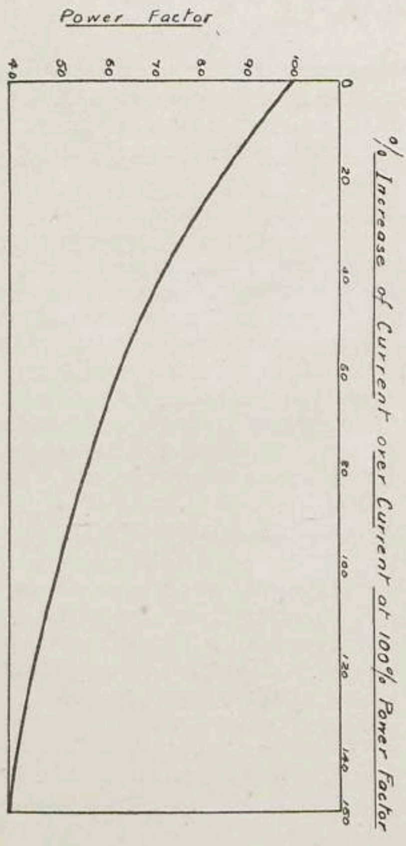
$$\frac{1{,}500 \times 4{,}400 \times 2.5}{6{,}600^2 \times 2.5 \times .75} = .2 \text{ sq. inches.}$$

Cable Required to Supply Load at Unity P.F.—

$$\frac{1{,}500 \times 4{,}400 \times 2.5}{6{,}600^2 \times 2.5 \times 1} = .15 \text{ sq. inches.}$$

Two and half miles .15 sq. in. cable, £5,500.
Two and half miles .20 sq. in. cable, £6,900.
Extra cost of .2 sq. in. cable, £1,400.

If it were considered advisable to have duplicate feeders, the additional cost would be £2,800.



The trunk feeders are not the only portion of the system affected, the low tension mains carrying large currents also become

overloaded and require strengthening at considerable cost. It may be put forward that a system will have large induction motors running at high load factors, and that my view is pessimistic, but I am prepared to prove that for every one 100 H.P. motor there are 20 motors not exceeding 10 H.P. running at the same time, and not more than 50 per cent. load factor.

At all times the voltage regulation of a system is a troublesome business, and, with a lower power factor it becomes a source of worry to the operating engineer to keep the pressure within limits, to prevent complaints from customers.

In the case of rotary converters, the regulation will influence these machines, and cases have arisen with rapid voltage fluctuation, these have flashed over on the D.C. side, putting out the substation.

Pulsations may be set up due to line drop, with the result that providing the synchronising current is insufficient a fish over will take place. The line drop is directly influenced by the value of the power factor.

In the case of transmission lines operating at low power factor, due to the line drop, the carrying capacity is considerably reduced. In table 3, with a given line drop the carrying capacity of a 13-mile line is given The maximum line drop for good regulation has been taken; in actual operation these limits would not be reached.

Table 3.

13 Mile Transmission Line.

.75	2992	3750
.80	2948	4000
.85	2936	4250
.90	2880	4500
.95	2728	4760
1	2160	5000

Having said so much against a low power factor, it is safe to assume that the question would be asked, how can the power factor be improved, and by what means?

Power Factor Correction.

To correct for low factor the following apparatus is commercially at our disposal:—

1. Synchronous motor.
2. Synchronous condenser.
3. Rotary converter.
4. Phase advancer.

Synchronous Motors.

These are in many cases installed on large systems for power factor correction. When used for this purpose, it is necessary they be specially designed, so far as the fields are concerned, to enable them to deal with the large exciting currents necessary for the power factor to be varied over a wide range. It is common for such machines to operate with a leading power factor of .5 on systems having a low lagging power factor. It must not be assumed, that by installing a synchronous motor of a size to suit your mechanical driving requirements, that the system will be improved, this is not so, unless the machine is of such size that it can supply the wattless current, besides doing the mechanical work necessary.

The point arises that by having synchronous motors on the system for future requirements instead of induction motors, the power factor trouble will disappear and we shall have unity power factor for all time.

Invariably a consumer when purchasing a motor follows his own ideas, and does not consider the convenience of the supply authority so far as the power factor is concerned.

In the case of a synchronous motor, and I am now considering the self-starting, self-symchionising type of commercial machines, the plant will consist of motor, exciter, starter, and should include a power factor indicator.

A consumer will not install such apparatus and trouble to keep the field current adjusted to such a value as required, for the motor to operate at a leading power factor.

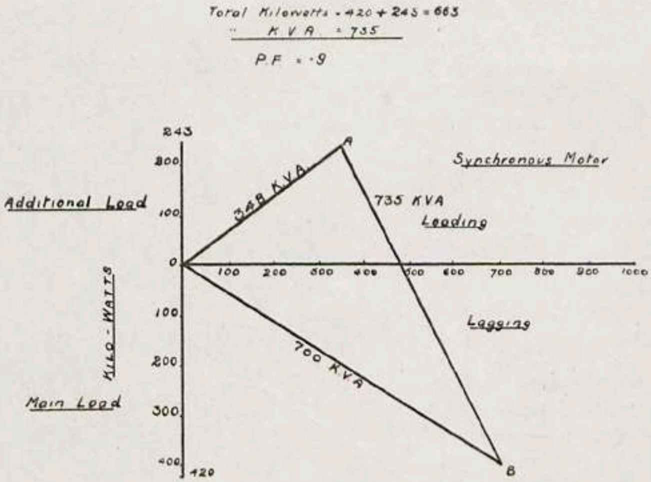
I think I am safe in saying that not one consumer in a hundred would entertain the idea, when he can have a plain induction motor. So far as the consumer is concerned, it makes no difference to him if his motor is loading the mains with wattless current, he pays only on the true kilowatts taken. If the load is supplied from a power plant in connection with a manufacturing or private concern, then the question of installing synchronous machines is in the interest of the power plant owner; entirely different conditions from those of a power supply authority.

Capacity of Machine Required for Power Factor Correction.

A simple method of arriving at the K.V.A. of a machine required for power factor correction is given in Curve "A." This method is used by a well-known English firm, the Lancashire Dynamo Co., who make a speciality of self-starting synchronous motors for power factor correction. To ascertain the power factor correction by the addition of a certain size synchronous motor, the procedure is as follows:—

On a vertical scale set off the true kilowatts both for the load and synchronous motor, on the horizontal scale set off the kilowatt

amperes at the power factor of the true kilowatts. Join up the points A.B., this will give the total K.V.A. of the circuit.



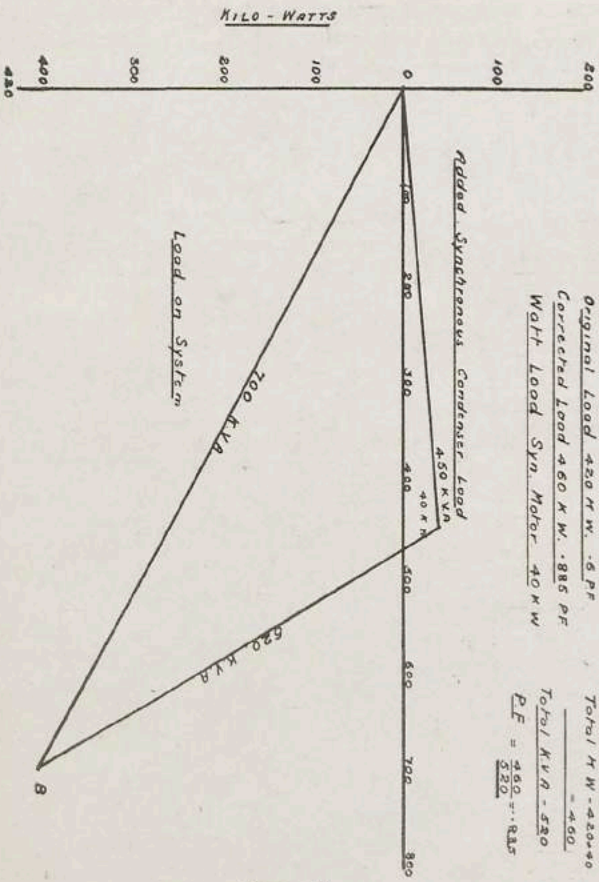
To find the power factor, add the total kilowatts and divide by the K.V.A.

In the case of Curve "A" the power factor will be as under:—

$$\frac{\text{True Kilowatts}}{\text{Kilowatt Amperes}} = \frac{663}{735} = .9 \text{ Power Factor.}$$

The original load was 420 kilowatts at .6 power factor, or 700 kilovoltamperes, the corrected load is 663 kilowatts, with 735 kilovoltamperes, the system being improved from .6 to .9, with only an increase of 35 kilovoltamperes.

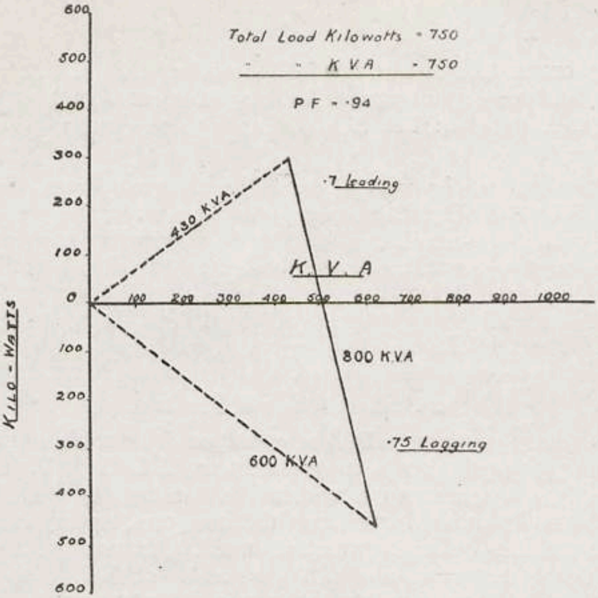
If a synchronous motor is to be used for power factor correction only and to perform no mechanical work, then the size required can be obtained from curve "B." This is similar to curve "A," with the exception that the kilowatts only represent the losses in the machines. By the addition of a 450 K.V.A. synchronous motor, the power factor has been increased from .6 to approximately .89, the load of the motor including losses being 40 K.W.



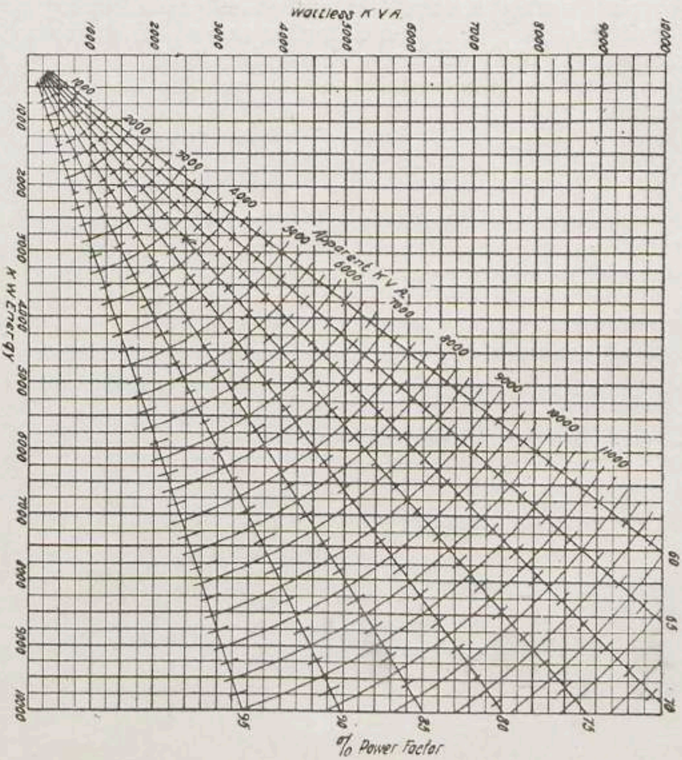
CURVE B.

In one particular instance of a load of 600 K.V.A. at an assumed power factor of .75, with the addition of synchronous motor of 430 K.V.A., the power factor could be improved to .94, by operating the motor at .7 leading power factor. This curve also brings out the proof of the earlier arguments that a machine too small would be of no value.

The B.T.H. Co. have also built some synchronous motors of 202 K.V.A. 440 volt 40 cycles for power factor correction. They are capable of giving an output of 175 B.H.P., and at the same time supply a leading current equivalent to 140 K.V.A., which is sufficient to neutralise the lagging current taken by 450 H.P. of induction motors.


Total Load Kilowatts = 750
" " K V A = 750
P F = ·94
·7 leading
430 K.V.A
K. V. A
800 K.V.A
·75 Lagging
600 K.V.A
Kilo - Watts

Curve C.


wattless K V A.
Apparent K V A.
K W Energy
% Power Factor

The curve "D" is useful for obtaining the K.V.A. capacity for a synchromous motor used as a synchronous condenser doing no work. To obtain the K.V.A. capacity the curve is used as follows:—

If the load on the system, or at the Power House or Sub-Station is 6,000 K.W. at .75 power factor, run along the vertical line until it cuts the power factor line, read the wattless componant on the left for the power factor, in this case 5300 K.V.A., follow the vertical line until it cuts the power factor that the system is to be raised to, say .95, the wattless componant for this power factor at 6,000 K.W. is 2,000 K.V.A.

Synchronous condenser capacity required =5300−2000=3300 K.V.A.

ROTARY CONVERTERS USED FOR FACTOR CORRECTION.

The rotary converter's field of operation is limited, inasmuch as it can only be used when a conversion from A.C. to D.C. is required. As it is a synchronous machine, it can be adjusted to draw current at unity power factor from the line, or a leading current as may be required. The commercial machine is not suitable for power factor correction above 10 per cent. of its capacity. If there are a number of rotary converters operating on a combined tramways and industrial power system, the running machines can be operated with the fields over excited to give a leading power factor of .95 to .9. With the field further excited, if this is possible, the current supplied will cause overheating in the slip ring taps on the armature. The stability of the machine to remain in synchronism would also be lessened, and safe operating conditions impaired.

INDUCTION MOTORS.

The choice of the speed of induction motors can influence power factor considerably. The higher the speed, the better the power factor; slow speed induction motors are the very worst form of commercial inductive apparatus possible to connect to a system. I have seen a colliery winder operating at .5 power factor, with a power factor of only .35, when running up to speed; the effect on the supply system is very severe, such could only be tolerated with very large plants.

Table No. 1 gives the power factors at full and half load for various speeds of induction motors.

Table 1.

Horse Power.	Speed.	Power Factor Squirrel Cage Motors.	Power Factor Slip Ring Motors.
10	1200	.9	.84
10	800	.89	.85
10	600	.84	.78
10	480	.80	.75
10	400	.75	.71
10	300	.72	.66

Table 1 (*Continued*).

Horse Power.	Speed.	Power Factor. Squirrel Cage Motors.	Power Factor. Slip Ring Motors.
20	1200	.91	.87
20	800	.90	.87
20	600	.86	.82
20	480	.80	.77
20	400	.80	.77
20	300	.75	.70
5	1200	.88	.80
5	800	.88	.83
5	600	.81	.75
5	480	.78	.69
5	400	.70	.65
5	300	.70	.63

Phase Advancers.

Of late great hopes have been set on phase advancers as a means of power factor correction for large induction motors. Successful machines have been put into service by the

Sandycroft Foundry Co., D. G. Kapp.
British Westinghouse Co., Miles Walkes.
Brown, Boveri and Co., Scherbrum.

The function of the phase advancer lies in supplying the magnetising current to the rotor at the frequency of the slip, resulting in reducing the wattless kilovoltamperes and improving the power factor on the motor. I do not propose, even if I were able, to describe the various technical details of the several phase advancers now on the market. To pursue the subject I would recommend anyone to the I.E.E. journals Vols. 50 and 51, in which several articles on the subject will be found.

The information given in Table 2 was taken from a Westinghouse phase advancer when this machine was on test, and gives one an idea of the improvement which it effected on the power factor of the motor to which it was connected.

Table 2.

Total Load on Power Plant.

	Amperes per phase.	Volts.	Power factor.
Advancer, out	325	440	.7 lagging
Advancer, connected	240	440	.92 leading

Motor Load Only.

	Amperes.	Volts.	Power factor.
Advancer, out	105	440	.74 lagging
Advancer, in	97	440	.96 leading

Three motors were installed at the Royal Albert Docks, pumping water for the Port of London Authority. These were supplied with current from the mains of the West Ham Corporation. Each motor is coupled to a centrifugal pump for emptying a graving dock. As the speed of the motors is low, the power factor at full load was only .55. This was found to be a serious matter, so far as the power station and mains were concerned, and when two pumps were working, each taking 400 H.P. the current drawn from the line was very heavy. Phase advances were fitted to these machines, with the result that they now run with a leading power factor of .96. The wattless current drawn from the line was reduced by 85 per cent. due to the installation of the phase advancers on these particular machines. Here again with consumers' motors, they will not go to the expense of installing phase advancers on large motors for the convenience of the supply authority, when a plain induction motor will answer their requirements. These phase advancers were put in by the Corporation, and at their expense. A phase advancer is at a disadvantage for power factor correction, inasmuch as it only improves the power factor on the particular motor to which it is connected, and not the system generally. With this disadvantage I cannot see but that the field for phase advancers must be limited to specific cases.

Condensers.

Very little has been done by means of static condensers, although they have their advocates. At the present time they have not come commercially into the field of competition with synchronous machines and phase advancers.

General.

Where he current is supplied by a company or other authority, I would suggest that some arrangements be made with consumers having synchronous motors, or any motor drawing current at unity power factor from the mains, that such consumer be charged a lower rate than the consumer drawing current at say .75 power factor. In other words, charge for the kilovoltamperes supplied, and not kilowatts. If some such means were adopted I have no doubt that engineers having large motor installations would avail themselves of the lower rates by installing synchonous motors.

In conclusion, I would state that the use of power factor meters cannot be too seriously considered, and by installing such, a check on the system can continually be made, and one of the great evils of A.C. working be kept in hand and remedied before the effects are only made evident by the requirements made for plant and mains.

POWER FACTOR AND ITS EFFECTS UPON ELECTRICALLY SUPPLIED SYSTEMS.

Discussion.

Mr. Gardam: It is not to be expected that individual consumers will bear any expense in improving the power factor of a system, for the reason that it should be borne by all of them, as all are indirectly benefited by a reduction of station costs, but the Government scheme is fortunate in having itself as a big consumer and should be able to instal, in such places as suited their requirements, synchronous motors to improve the power factor. In Sydney much power factor connection is obtained by synchronous motor generator sets installed in sub-stations for the supply of direct current in the entire of the City, and for this and many other reasons, it is a pity that Perth did not retain the D.C. system for the centre of the city. In systems where the the day load is light, that is where lighting forms the bulk of the load, the effect on capital outlay due to poor power factor is not so serious as in a supply consisting mostly of power load, for at the time when the P.F. is at its lowest, there is plenty of plant available to supply the wattless load, whilst at the time of the heavy load the power factor becomes more reasonable due to the preponderance of non-inductive load. We are much indebted to Mr. Taylor for bringing this interesting subject forward, and I have much pleasure in proposing a hearty vote ot thanks for so doing.

SOME PRACTICAL PHASES OF GYROSTATIC ACTION IN ENGINEERING.

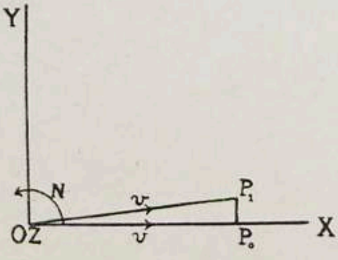
By Professor A. D. Ross.

Gyrostatic action enters into many problems in practical engineering and the general nature of its effects are fairly well known. But while its study in a qualitative manner is taken up by most engineers, a quantitative determination of its effects in particular cases is rarely made. This is doubtless due to the abstruseness of the usual mathematical treatment of the subject which is based on the Lagrangian method. As a result the great physical interest of the problems has been obscured, engineers have neglected them, and the magnitude of the couples called into play in gyrostatic action has in some cases been greatly over-estimated while in others it has been underrated with disastrous results.

It is possible in many cases to calculate the gyrostatic couple without recourse to the advanced mathematical methods used by Kelvin, Routh and others. There is a comparatively simple vector method which suffices to derive the formula necessary in most engineering problems in gyrostatics, and in this paper I propose to give an outline of the method and a reference to a few problems which come under it.

At the outset it will be well to establish a theorem regarding rotating axes which is not so well known as its wide range of application certainly warrants.

Let v (Fig 1) be any vector quantity associated with the direction of the axis OX, which axis is turning with angular velocity N towards the instantaneous position of the axis OY, an axis which remains at right angles to OX. Then in a very short interval of time t, v, will have turned through a small angle NT, from the initial position OP_0 to the position OP_1 There is now a component P_0P_1 of the vector quantity in the direction OY, and if the angle P_0OP_1 is very small we may write $P_0 P_1 = v \sin (Nt) = vNt$. Since then vNt is the growth of the vector quantity in the direction OY in time t the rate of growth is clearly vN.



It is to be observed that there is no change in the magnitude of the vector v; there is only a change in its direction which gives a rate of growth of this quantity in the direction OY perpendicular to the axis OX. The case is exactly analogous to the acceleration towards the centre possessed by a body moving with uniform speed round a circle. The velocity of the body is changing in direction although not in magnitude.

Conversely, if a rate of growth vN of a vector quantity v is required in the direction OY it may be supplied not by a change in the magnitude of such a quantity, but by the rotation of v at rate N towards the instantaneous position of OY,

Let now OX (Fig. 1) represent in plan the direction of the axle of a gyrostat. Let I be the moment of inertia of the flywheel about the axle, and n the angular speed of the wheel. Then In is the angular momentum or moment of momentum. Let now forces be applied in a vertical plane to the axle of the gyrostat so as to tend to cause rotation of the axle in a counter-clockwise direction as seen by an observer looking horizontally along the line YO. Then OY is the couple-axis. Let C be the magnitude of this couple tending to rotate the axle of the gyrostat about the axis OY. Then C is numerically equal to the rate of growth of angular momentum about OY. Now if N is such a quantity that $C=(In)N$ then this required rate of growth C of angular momentum about OY will be supplied, *not* by the axle of the gyrostat tilting from the horizontal plane, but by the axle OX turning in the horizontal plane with angular speed N towards OY, This motion of the axle at rate N is called the "precession."

Similarly, if a flywheel of moment of inertia I and angular speed n has its axle turned at angular speed N about an axis OZ (perpendicular to the plane of the paper in Fig. 1) from the position OX towards the position of OY, an externally applied couple of magnitude $C = InN$ must be supplied about the axis OY to balance the gyrostatic action. In applying this principle due regard must be paid to two points, viz., the directions of the axes and the units. The spin-axis OX coincides with the direction of the axle of the flywheel and is drawn from O towards that side from which the rotation of the wheel appears counter-clockwise. Similarly, the couple represented by the couple-axis OY is such that, observed from Y in the direction YO it tends to produce counter-clockwise turning about OY. Moreover it will be observed that the precessional motion is such as to make the spin-axis move towards the instantaneous position of the couple-axis.

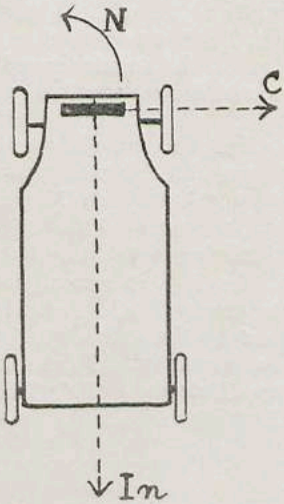
As regards the units to be employed, the equation $C=InN$ is adapted to absolute units. If for C we write Fd where F is either force of the couple, and d is the couple-arm, then F must be in poundals, d in feet, n and N in radius per second, and I in lb.-ft.^{2}

units. Adapting to engineer's units, viz., F in lbs. weight, and n and N in revolutions per minute, we have the equation transformed to

$$F.d = \frac{4\pi^2 \; InN}{32.2 \times 3600} = \frac{InN}{2940} \text{(approx.)}$$

The above formula enables the magnitude of the gyrostatic action to be calculated. We shall now consider its direction in a few special cases.

In a motor car the spin axis of the flywheel is drawn to the rear (See Fig. 2). If therefore the car is steered to the left round



a corner, the rotation of the spin axis is counter-clockwise as seen from above, and hence the couple axis is drawn upwards from the car. The precession is therefore such as to tend to turn the car counter-clockwise as viewed from the right. Hence there must be an increased pressure between the ground and the front wheels and a diminished pressure at the rear wheels which might result in skidding of the driving wheels. On the other hand steering the car sharply to the right would reverse the effect, and the diminished weight on the front wheels might tend to affect the steering. Similarly, when a car is running over the highest point of an arched bridge there is a tendency to swerve to the right, and when at the lowest point of a sharp dip in a road there is a tendency to swerve to the left.

The gyrostatic action of the wheels themselves of a motor car or locomotive is comparatively small as compared with the other forces on such bodies, but it is to be noticed that the action is such as to diminish the maximum speed at which the body can be

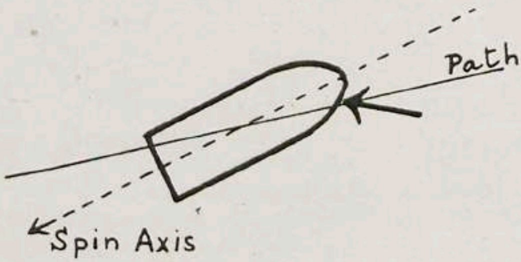
driven round any given curve without capsizing. The gyrostatic action is of greatest moment in the case of light structures with relatively heavy rotating mechanism driven at a high speed, such as one has in aircraft.

In the case of the turbines of ships the gyrostatic action is not of any great importance, provided the holding down bolts of the rotors are kept tight. A simple calculation will show this. Taking the case of one of the turbine Cunard liners, we have three rotors. The rotor on the central shaft has a mass of about 40 tons and a radius of gyration of about 3 feet, giving a moment of inertia I of $40 \times 3^2 = 360$ in ton-ft^2 units. For the rotors on the wing shafts we have the mass 80 tons and radius of gyration 4 feet in each case, giving I as 1280 ton-ft^2 units. The axis of rotation of each rotor being fore and aft, gyrostatic action cannot be set up by rolling of the ship, but only by pitching or by the vessel being steered to port or starboard. Take the case of pitching as that in which the precessional motion is fastest. If the pitching has, say, an amplitude of 6 degrees in a period of 6 seconds, we get, assuming the motion to be of simple harmonic nature, a maximum angular velocity N of 12π (6×57.3) radians per second. And, since the speed of all the rotors is 200 revolutions per minute, $n = 400\pi / 60$ radians per second. Hence the maximum gyrostatic couple as given by the formula $C = InN$ is 92 for each wing-shaft rotor and 26 for the central rotor, the numbers being in ton wt.—foot units. If we divide these numbers by the distance in feet between the two sets of holding bolts of the turbines, we get the shearing force in tons weight on each set. Clearly the forces, although reversed every three seconds, are not of a magnitude to influence the size of bolts necessary nor to cause any danger provided the bolts allow of no play.

The only matter requiring further investigation is the question whether the alternating stresses could through coincidence with the free-period of the structure produce dangerous vibrations in the shafting or in the framework of the ship's hull. The rotor of the turbine and its connected shafting form an elastic structure, and any transverse flexural wave will run along the shaft and undergo reflection at the first bearing. In view, however, of the lateral stiffness of the shafting and of the rotor, it seems impossible that synchronism could occur between the period of transverse elastic vibration and that of the pitching. We have therefore to consider only the effect of the gyrostatic stresses on the ship as a whole. It is to be noticed that the wing-rotors rotate in opposite directions and therefore balance one another except as regards alternating internal stresses in the intervening frame work, alternately compressing and elongating the transverse portion forward, while the aft portion is alternately elongated and compressed. The net effect however on the entire hull is that of the central rotor. The framework of the hull, like a rod free at both ends, has for its funda-

mental mode of transverse vibration two nodes, for its next harmonic three nodes, and so on, the frequencies being in the ratios 9 : 25 : 49 : 81 : etc. Since in a transatlantic liner the fundamental vibration would probably have a period less than a second, there seems no likelihood of resonance effects of any importance through gyrostatic action.

In conclusion, it may be interesting at this time to indicate the gyrostatic effects in the case of a rifle bullet or shell. These elongated projectiles are, by the rifling of the firing -piece, given a rapid rotation about the axis of figure. This rotation gives the axis of the projectile a quasi-rigidity which results in its gradual angular separation from the tangent to the curvilinear trajectory. The rifling of a service rifle is left-handed, and so the spin-axis of the bullet is directed towards the rear. As the direction of the motion in space becomes less inclined upwards, the air resistance comes to act most strongly just under the apex of the bullet (See Fig. 3). There is therefore a rotating agency in the counter-



clockwise direction as seen from the right of the path of the bullet. The couple-axis is therefore drawn towards this side, and as the spin-axis moves towards it the point of the bullet deflects towards the left. As the bullet can move with least resistance in the direction of its apex, the vertical plane of the trajectory is deflected towards the left, causing a lateral drift from the plane of departure. Ordnance being rifled in the opposite direction, shells drift towards the right, the amount being about a yard in 1000 yards range, and increasing rather more rapidly than the square of the range. It is not, however, to be imagined that the shell finally strikes the ground with its axis tilted upwards at the same inclination as the line of departure from the gun. When the shell deflects to the right the new gyrostatic couple due to excess air pressure on the left side will lower the axis of the shell, and in addition we have complicated effects due to air friction and viscosity.

EDUCATION AND ITS CONNECTION WITH THE REAL PROBLEM BEFORE ENGINEERING SOCIETIES.

By Alfred Tomlinson.

Do we think the lawyer or the business man or the man in the street has anything like a true understanding of the Engineer and his ideals? We are quite sure in our own minds that their ideas on this subject are far from the truth. We often meet persons who might be expected to know better, who can be convinced only with difficulty that engineering is any more than surveying; that railway engineering is not merely another name for plate-laying; that sanitary engineering does not mean plumbing.

It appears that Engineers in the eyes of the public are "but hewers of wood and drawers of water," men of low degree. Do we need anything different, do we require the higher approval of our fellow man? Some of us, perhaps, are not interested. Without doubt the general attitude of the engineer is one of indifference in this regard, and so the misconception is allowed to remain to the detriment of the Engineer. If this condition is to be changed, how can it be accomplished and who should attempt it? It has been said that this is a live problem before the Engineering Societies, at least, of the British Empire.

According to the Institution of Civil Engineers, an Engineer "is one who directs the great sources of power in nature to the use and convenience of man." If the Engineer is really deserving of the name he will be engaged not only in doing this work but in doing it efficiently and economically, so that it is now usual to add to the above definition the following: "One who can do for one dollar what any fool can do for two." These two definitions, taken together, give a fairly complete characterisation of the Engineer; but in interpreting them we must not fail to take into account that human nature is not the least important of "the sources of power in nature."

We know that the Engineer is a student of natural science, a trained thinker and an experienced Applied Scientist.

The work of the Engineer differs in a very important respect from that of some other professions. The Doctor, in most cases, fights single-handed for the health or life of his patient. The Lawyer usually conducts his case independently, and for the sole benefit of his client. The Engineer, however, can do little or nothing by himself, and only rarely for an individual. His work is done in groups or gangs, by gangs and for gangs. This may be one of the causes for the prevailing misconception that we are but workers in stone and in wood.

Now, Engineers do not speak or talk about Engineering except to themselves, and in their own language, and so the question might be asked are we a tribe? Undoubtedly we use peculiar terms and expressions, and evidently we suppose, and this appears to be our characteristic, that it is our business alone to talk about engineering, and so nobody else does. We are left alone. Doubtlessly in time some explorer from outside will discover us. At present we are unknown. Those outside us recognise that we are different from them. The argument, then, is that we must be inferior or superior to them, and naturally we are looked upon as being inferior.

One of our functions should be to guard ourselves. Those entering the profession should be protected. Yet we do not take the trouble to fight so as to enlighten and correct. We have a good excuse for this indifference, it may be tribal pride, for our work is usually very variable and interesting, and we are so busy with it that we have little time and energy for anything but our work.

*Again, to use the words of Professor Haultain, "we take the trouble neither to dress nor speak the part." To the public mind "dignity and learning," "valour and status" are respectively intimately associated with "wig and gown" and "uniform and decorations," for they convey the fact plainer than any words, that the man within is of high worth and status in the general scheme of things. However, dress, I am afraid, is denied us. We are so young—characteristics hallowed by time are not for us. Publicity of some kind we need, perhaps, more than anything else. It is certainly essential for our welfare that those not of our tribe, society or profession—call it what you will—should know what "manner of men we are." We must exhibit the man, and with him his methods and ideals, and, being understood, the man will be known to be of high worth in the general scheme of things, and of high degree. The ordinary methods of publicity either offend us or are not for us.

The real problem before us, before Engineering Societies, is to find suitable publicity.

I have a solution to offer to this problem. Briefly it is to be found in Education. At the present time the "ordinary training and education" does not enable and so prevents the work of Applied Scientists or Technologists—like Engineers—being understood. There is no doubt many of the most prominent Englishmen understand nothing of those Sciences which are transforming all the conditions of civilisation. It is believed that this is the real cause of the misunderstanding between Engineers and those outside the profession, and only a universal training based on scientific methods will be of any real use to us, the contention being, of

*The author has quoted freely from a paper in "The Weilder of the Weapon," by Prof. Haultain, of Canada.

course, that then the public will be able to realise what "manner of men we are." Hence it is necessary for our welfare that the training of our young people should be on a different basis. From quite a different standpoint to this, others maintain that a change in the present educational methods is essential for the welfare of the race. The matter may then be considered to be very important in all ways, and it is now proposed to look into it generally.

At the outset it must be understood that the remarks are particularly directed against the system at home in the British Isles. Out here in Western Australia the educational outlook in certain directions is comparatively satisfactory, although in the actual training there are perhaps too many pupils per teacher, and again, teachers are badly paid. The influence of our University is in the right direction, and this is because it is not hampered by being saturated, as in the older Universities, with what may be termed "orthodox or traditional culture," and thus, to give only one example, does not insist on feeding the minds of the young on the dry husks of dead languages.

It has been usual to leave the elementary training of our children—the all-important preparation for their future—wholly in the hands of the don and the schoolmaster. Through this apathy of parents and lack of public interest too much has been left to chance, and, as might be expected, our racial characteristic—muddling through—has not given the best result It is maintained that the present ordinary education is, to say the least, unsatisfactory and unsuitable for modern needs.

A well-known English Scientist recently said "that if the British Nation really wished to become leaders in the World's Work it would have to scrap its present methods of education and teach science instead of classics, knowledge instead of accomplishments." Thereupon the dons and schoolmasters in England, who have been rather out of the limelight of late, arose in their might and in the newspaper columns proved that the glory of England was bound up in Latin grammar and rooted in Greek particles.

This is very interesting indeed, for, as a matter of fact, the battle, Science v. Classics, was fought and won by the Scientists about 50 years ago.

It must be remembered that up till the middle of the nineteenth century fifteenth century ideals prevailed; and these ideals were saturated with mysticism. Knowledge was hardly to be desired lest the charm of mystery should be lost, and science was not welcome since it laid bare many fallacies. Science in the temples of medieval learning was considered to be a defilement. The learned professions of Law and Theology did not deal with

materials, and even Medecine was unpractical. Why was all useful work tabooed? Was it a relic of feudal tyranny?

In this atmosphere laden with the blinding dust which the devotees of the old traditional culturist school had raised, a few souls made an attempt to fan and clear away the obscuring haze or fog. Briefly, it was shown by Huxley that "education is learning or acquiring a knowledge of the rules of the mighty game of life. These rules are not written in Latin or Greek or any particular language: they are only to be understood by a study of the laws of Nature. That the only true education is the endeavour to train the intellect to the understanding of things and their forces, and to fashion the affections and will into a real desire to live in harmony with Nature's laws. Therefore, science—organised knowledge—is the basis of all real education. Classics, although desirable, are not of primary importance." Others contended that the controversy as to the relative merits of science and the classics in education missed the mark by placing the emphasis in the wrong place. It was argued that the method rather than the subject was of supreme importance.

Anyhow, the scientists left the dons and schoolmasters scientifically strafed.

Then the men of science returned to their laboratories and expected that the political undertakers would come along and clear the field. But politicians were then much as they are now. Nothing was done. The dons and schoolmasters laid low and said nothing, and continued in their evil ways with but few real changes up to the present time

If you look at the lists of the heads of the colleges and public schools at home you will find very few science men amongst them. Science is still considered to be of secondary importance. This is further emphasised by an examination of lists like those of the Civil Service.

At first sight it does appear strange if the men of science were victorious in the educational battle that nothing really ever came of it. However, the explanation is, I believe, a simple proposition of politics that it takes the masses, the faithful who cling to famous watchwords like "wait and see," many generations to make up their minds that we want a new world if we are to have any world atall. For only a new-educational world with new ideals will be of much service to us. Huxley and others only finished the argumentative part of the business; the practical destruction of the old and the building up of the new requires the backing of the people—necessitates great political physical strength.

Without doubt, the training, particularly in secondary schools, is as if all average boys were proceeding to take classical studies

at a University, and preparing to be clergymen and schoolmasters. Medieval ideals are still adhered to.

The dons and schoolmasters at home are now asking for a new trial with a new jury.

The Pure and the Applied Scientist believes that the basis of educational method should be the "idea of learning by doing." As Engineers, this fundamental idea is very familiar, for it is the basis of our technological training. Eye and hand are brought into action to direct, deepen, and vivify the mental impression.

Now, the average boy cannot take to abstract reasoning—to him there is something unreal about it all—and he is called stupid. Is it not absurd to call a boy stupid because he finds the study impossible? It is obvious to all except to the teacher who is generally permeated with orthodox culture, that there must be something amiss with the method of presentation of the subject. Is it likely that a boy can get real mental training through any subject of study unless he is interested in it? Why not do away with the artificial atmosphere and interest him whenever possible, in the laboratory or "do it yourself" methods—that is, acquaint the boy with real or concrete things first, and afterwards proceed to ask him to reason about them. In other words, there must be more doing things with the hands and less droning over books.

At some future date perhaps you will allow me to give more details of the working out of this Applied Science method.

It is contended that in the orthodox, the classic, to which must be added the old scientific method—there is the danger of the abstract, and the study of the abstract is the path that leads to acceptance and absorption on faith rather than by proof. Now Science, particularly Applied Science, because it is applied essentially must be concrete, and, as is now agreed, must be taught by the experimental "learning by doing" method. By this experimental method, in the laboratory, the student, by his own effort and observation, acquires unconsciously the Scientific Method of thought. He learns the value of truth as established by himself, which must be ever greater than that taken on faith from someone else. This is the essential difference between the Scientific and the Classical Method.

"Scientists" aim for "truth and verification," and "the classicals" live on "faith and precedent." It is not suggested, of course, that the "classicals" can do anything else.

What is contended, however, is, firstly, that the result of a classical training does not fit in with the general scheme of things nowadays, such as practical requirements necessary to enable one to live. A century ago the classical method, perhaps, was alright,

but not nowadays, owing to the enormous changes in our mode of living due to industrial developments. And, secondly, the scientist maintains as a principle that the boy should continue to train within reason, in the same natural way as he did during the first two years he was born, that is, by the "learning by doing" method.

Have you given thought to the wonderful truth that the baby is its own schoolmaster during the earliest years of its life and it never apparently has a better? If you watch a baby you soon come to the conclusion that the baby works on similar lines to the scientist. If you give a baby a biscuit, it cannot at first find its way to its mouth; it jabs the biscuit in its eye, but it proceeds by practical experiment to control its muscles in accordance with the laws of Nature, and ultimately attains its object, the way to its mouth; it afterwards sleeps, and perhaps dreams, and stores up energy for new victories. In the same way walking and talking are mastered by the scientific baby on scientific principles. It appears to me that the amount of real hard self-education that a baby does in the first two years of its life is remarkable. Then it falls into the hands of the loving and unscientific parent ,and the bright outlook of its career is generally further darkened by the orthodox schoolmaster.

Now, as Engineers, we are directly concerned in this question of the right kind of education and training. The matter is of great importance to us, quite apart from the necessity for an alteration for the welfare of the race in general, for it is maintained that "education with scientific methods as the basis of it" is the solution of the problem before Engineering Societies, the question of publicity, the question of our welfare, and so we must exert all our influence to bring about the change which should have taken place long ago.

When a training or knowledge of scientific method is insisted upon in our educational system, then the Engineer and his ideals will be truly understood by all—by the lawyer, the business man, and the man in the street. The Schools and Universities will then be looked upon as laboratories instead of libraries. But it is no use preaching or working. The argumentative educational battle was won long ago, although the "pros and cons" are now somewhat different to then. The practical business of shifting the orthodox methods from their dug-outs and trenches will want something stronger than words, even if they are high explosive words. The rooting out requires the bayonet of the "man in the street."

RANGE-FINDING.

By Professor A. D. Ross.

The importance of accurate range-finding in modern warfare cannot be over-estimated. The cost of ammunition and the comparatively short life of heavy guns alone make it desirable that every shot should tell. And since the development of aviation has rendered the secret movement of troops impossible, there is no opportunity left of a surprise attack unless gun-fire can be opened unexpectedly without the firing of a series of range-finding shots.

Early types of range-finders depended either on the variation with distance of the apparent (angular) size of an object of known dimensions, or upon the solution of a triangle as in surveying. The former type was unsatisfactory in practice, owing to uncertainty (perhaps 6 to 8 per cent.) as to the true size of the test object—usually a man—and also owing to the actual difficulty of finding such a visible object at the enemy's position. Modern range-finders have developed from the second type, the developments being remarkable in the extreme shortness of the modern base and the accuracy with which the base angles are measured.

In all range-finding methods now used and depending on the solution of a triangle, one of the base angles is a right angle. Thus in depression range-finders, such as are used on elevated coastal forts, the base is the known height of the fort and is perpendicular to the surface of the sea. Measurement of the angle of depression of a distant ship below the horizontal plane gives (as its complement) the other base angle, viz., the angle between the base and the line of vision. Thus the triangle may be solved. As a ship 10 miles distant from Gibraltar is seen from the top of the rock, 1,408 feet high, at an angular depression of about a degree and a half, the range can be found with considerable accuracy, an error of 10 seconds in the angle giving an error of only some 30 yards in the range.

It is evident that this method is exactly similar to that in which the distance of the enemy's trenches is determined by measuring at the gun station the angular elevation of an aeroplane passing exactly over the enemy's position at a known and pre-arranged height. It will also be seen that this method can be used in cases where undulating ground or intervening hills hide the enemy's position from the artillery base, provided, of course, that the line of vision to the elevated aeroplane clears these obstructions.

The principle of the mekometer and the telemeter is similar to the above, except that the plane of the measured triangle is horizontal instead of vertical. In the mekometer method two small instruments are used, each measuring about 4in. or 5in. x 3 in. x

2in., and weighing rather less than 3lbs. One is an optical square; the other is similar in principle to the box sextant, only, as the base is a fixed length and the other base angle is 90%, the measuring mekometer does not give on its scale the size of the base angle, but the range in yards. The base is formed by a cord, 25 yards long, connecting the two instruments. The cord is of hemp, covered with silk and a paraffin wax preparation to withstand damp. This protection, however, is unsatisfactory after some service, and the resultant errors in the readings are rather large.

The telemeter is a somewhat more elaborate instrument mounted on a tripod stand. The base-line is measured by the instrument itself by setting out a shorter subsidiary base. But for the time taken to secure measurements, the telemeter would be a highly efficient instrument.

Both mekometers and telemeters have however, a serious defect in so far as they are two men range finders. There is always a risk that the two observers will not set on the same object, and, in view of the precision required in range-finding, it is essential that the instruments be set not only on the same object, but on the same part of the same object. Accordingly one-man range-finders have come increasingly into favour despite the fact that they necessarily use an extremely short base-line. This difficulty has been to a great extent eliminated by the high perfection in the ingenious methods of angle measurement employed, and by the reduction to vanishing point of temperature effects and the like.

Of the one-man range-finders the best known is the Barr and Stroud, which has been adopted by the British Government, and by many of the leading nations of the world. The essential parts of the instrument are shown in Fig 1. *A B* is a long tube, shown in section in plan. It is arranged like a double periscope. To fix our ideas let the tube *AB* lie in the west-east line. At A, the west-end, is an opening *W*, through which a beam of light travelling south enters, and the glass pentagonal prism *P* (described below) bends the beam through a right angle to an easterly direction. The beam then traverses the object glass *L*, and meeting the vertical mirror *MM*, which lies north-west and south-east, it is reflected out southwards through the eye-piece at *E*. If the source of the beam is very distant, a second beam travelling almost due south will enter at the opening *w*, be bent through a right angle by the prism *p*, travel westwards through the lens *l* and through a prism *d*, of very small angle to the mirror *mm* situated immediately below *MM* and placed north-east and south-west. This beam therefore is also reflected out southwards through the eye-piece at *E*. Thus an observer at *E*, has his field of view divided into two parts, the upper part containing an image of what is

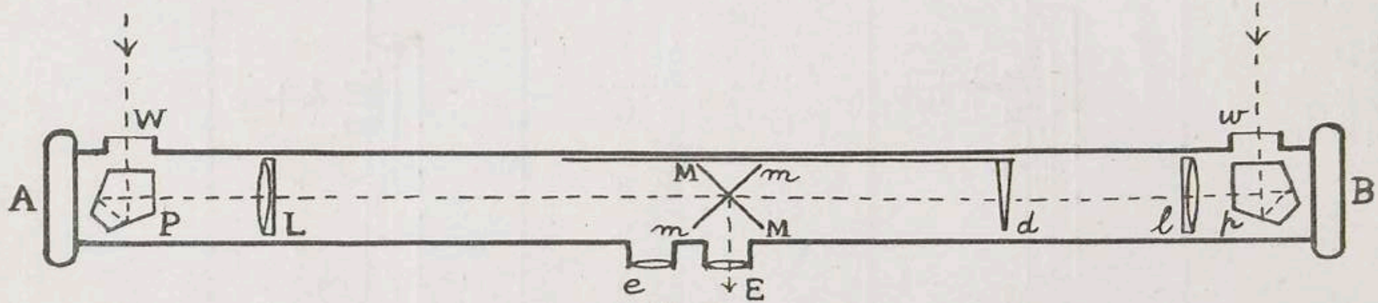


FIG. 1.

seen through *W* and the lower part what is seen through *w*. (See Fig. 2).

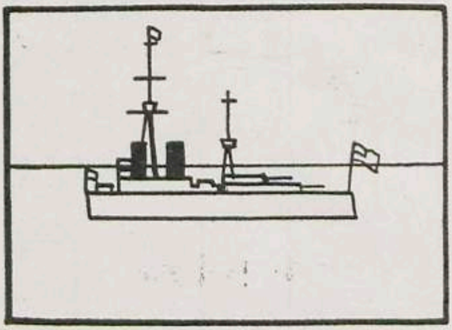


FIG. 2.

Evidently if the object under observation is comparatively near and due north of *W*, the rays of light travelling from it and entering *w* must be travelling silghtly east of south, and, after deviation at *p*, travelling south of west. They accordingly fall on the mirror *mm* near its south-west edge, and the two parts of the field of view as seen through the eyepiece no longer give a natural coincidence. (See Fig. 3). This displacement towards the left, of

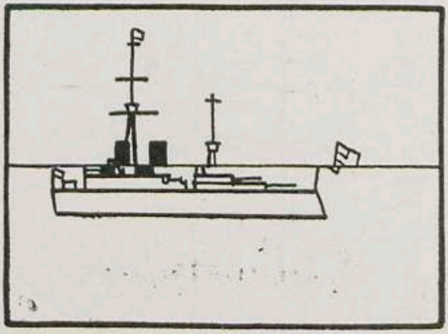


FIG. 3.

an object in the lower part of the field of view gives a measure of the nearness of the object. The distance of the object is not measured in practice by the displacement, but by the deviation to be made in the beam from *w* to annul the displacement. The displacement is annulled by the motion of the deflecting prism *d* in the

right-hand portion of the tube. As the prism is of very small angle it deflects the ray only very slightly to the northward and by a constant amount. Suppose the ray between *l* and *d* to be travelling very slightly south of west and between *d* and *mm* to be travelling very slightly north of west. If *d* is placed close to *l* the ray is only for a short distance travelling south of west, and for a much longer distance travelling north of west. On the other hand if *d* is close to *mm*, the ray for a considerable distance is travelling south of west, and only for a short distance north of west. In the first case the ray will fall at the north-east side of *mm* and in the second case at the south-west side; that is the image as seen in the eyepiece will in the first case be to the right in the field of view and in the second case to the left. By adjustment of *d* accurate natural coincidence can be obtained between parts of objects seen in the upper part of the field and in the lower. (See Fig. 2). The position of *d* is altered by a milled head screw, and an eyepiece *e*, enables the observer to read off the range on a scale moved automatically with *d*.

In most range-finders an additional lens system in one branch of the tube inverts the picture in the upper half of the field of view, as it is then rather easier to tell when exact coincidence is obtained in the two images of vertical objects.

The action of the pentagonal prism reflectors depends on the fact that a ray of light undergoing successive reflection at two mirrors *OA* and *OC* (Fig. 4) inclined at 45° is ultimately deviated

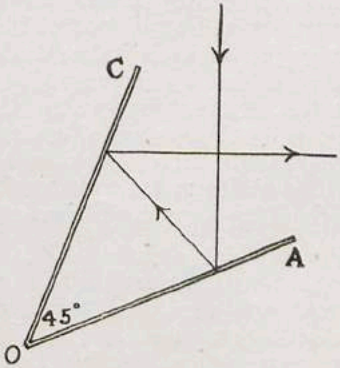


FIG. 4.

through 90°. The mirrors in the range-finder are the silvered surfaces *AE, CD,* of the glass prism (Fig. 5), and they are maintained constantly at 45°, as the intervening space is solid glass. The advantage of this method of deviation is that the emergent ray is not

sensibly affected by the rotation of the prism *ABCDE* through a small angle about an axis perpendicular to the plane of the diagram (Fig. 5).

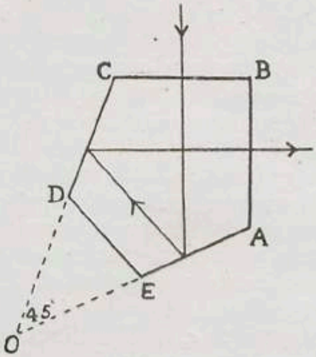


FIG. 5.

The range-finder is made in various sizes from about one yard base up to some 20 feet. An idea of the necessary accuracy of workmanship is given by the following figures. With an 8-foot base, the parallax angle is only 52 secs. for a 6-mile range, and to give the range to 20 yards the angle is required accurate to a tenth of a second. (A tenth of a second is the angle between two lines which diverge from a point and reach the opposite sides of the diameter of a halfpenny over 30 miles distant!).

It is evident that these range-finders are at once high precision scientific instruments and apparatus which have to withstand rough service. Every precaution is taken to have the instrument thoroughly aged and settled by jarring it repeatedly before its final adjustment at the manufacturing works. It can also be rapidly adjusted on service by observation of a star or test bar. Temperature effects are almost completely eliminated by mounting the optical parts on a fine girder metal framework kept at a uniform temperature throughout by a good air circulation.

One exceedingly valuable adjunct of the Barr and Stroud range-finder is a cylindrical lens astigmatiser which can be introduced into the optical path. By its use gun flashes and ships lights at night are drawn out into vertical lines suitable for setting the instrument. The astigmatiser can also be used effectively in daytime on open country where there are no conspicuous objects. Heaps of stones appear as a pattern of vertical light and dark lines of varying width which permit of accurate setting.

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